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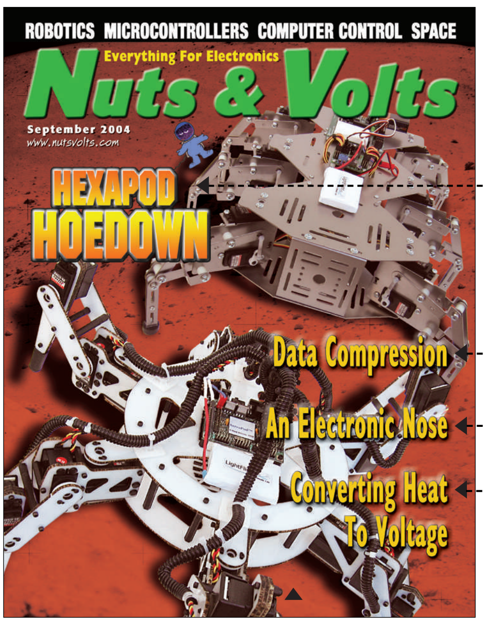

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Reader Feedback

Dear Nuts & Volts:

I was taken back to my college days at the University of Colorado by the article "A New Life for LORAN" (August 2004). I took power lab from Prof. Easton and electronic lab from Prof. Wicks in the same semester. There was a friendly exchange of barbs between the two; in particular, Prof. Easton accused the circuits lab of dealing in "sneak currents," milliamps vs. real currents of dozens or even hundreds of amps in the power lab. The last day of class, Prof. Wicks distributed data sheets for the F1086 tube, pointing out that the 12.6 volt AC filaments ran 200 amps, asking us to "Tell Prof. Easton that this is not a sneak current!" when we went to the final power lab class. Thanks for the memory.

Jerry Berry, BSEE '59
via Internet

Dear Nuts & Volts:

Having been a Loran A instructor during World War II, and having conducted the first airline evaluation of Loran C in the 1950s, I was surprised to learn from Clifford Appel's article in your August issue that Loran C is still alive and pulsing. However, he fails to mention what agencies might use it today. Considering that GPS seems to have become the method of preference for geographic position fixing in the 21st century, I would have thought that Loran C would have gone the way of Decca/Dectra, Omega, and the other navigational systems of the 20th century.

Also, I was very interested in Michael Banks' article about Hugo Gernsback. This is the first complete account I have ever seen of his life and accomplishments. Those of us who got our start in radio in the 1930s well remember waiting in anticipation each month for the latest issue of his *Shortwave Craft* (if I have the name right?).

Paul Rafford Jr. NY4L
via Internet

Dear Nuts & Volts:

While thumbing through your August 2004 issue, I came to the article "Just for Starters" by Mark Balch and was happy to see a section titled Ohm's Law. One of my minor hobbies is analyzing explanations of "Ohm's Law for beginners" to see how close to the truth the author came. (What does that tell you about my life!?)

People who work with objects that conduct electricity are often interested in knowing the current I that flows when a voltage E is applied, and the ratio of E/I of these quantities. This ratio turns up so often that it is handy to have a name and symbol for it, and in fact it has been given the name "resistance" and the symbol R. Thus, the expression R=E/I is not any kind of law, but simply a definition of resistance. Ohm's Law, on the other hand, is more significant than this. It is an experimentally determined law of nature, not just a definition.

So what is Ohm's Law? If we apply voltage E1 and measure current I1, and then apply a different voltage E2 and measure current I2, Ohm's Law states that E1/I1 will be equal to E2/I2. Since we have made a definition for the ratio E/I, and since the test voltages were arbitrary, another way to say this is R=constant. In other words, Ohm's Law states that the resistance of a conductor stays the same for any applied voltage. Since we all know this isn't true (visualize the characteristic curve of a silicon diode), why is Ohm's Law important? The answer, of course, is because lots of important devices do obey the Law for a wide range of voltages and currents. The diode just isn't one of them. Even for the diode, we can use the definition to calculate an effective resistance for a given voltage or current. But when we do this,

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Events, Advances, and News From the Electronics World

Advanced Technologies

Lords of the Flies

The hyperacute directional hearing of Ormia ochracea results from its unique ears, which are part of the prothorax behind its large head, as shown. Photo by R. Hoy and G. Haldeman/Cornell University. Copyright Cornell University, reproduced with permission.

Recently, some researchers at Cornell and Binghamton Universities (**www.cornell.edu** and **www.binghamton.edu**) have been spending a lot of time with flies. No, this is not a reflection of their personal hygiene, but an embodiment of a grant from the National Institute on Deafness and Other Communication Disorders (NIDCD, **www.nidcd.nih.gov**) that has underwritten a study of Ormia ochracea, which is a peculiar cousin of your common housefly. Most flies primarily eat plants and animals that are already dead or decaying, but Ormia is a parasitoid; it lives off of living animals.

When a female Ormia hears the chirp of a male field cricket, she flies to within a few inches of it, sneaks up on its back, and deposits larvae that eventually burrow down into the cricket. In a few days, the larvae emerge from the unfortunate, dead cricket and fly away, much as relatives flee from your home after devouring a huge holiday meal and finishing off all of the good Scotch.

Perhaps the most remarkable thing about this process is that, even though Ormia is endowed with the standard array of sensory equipment (compound eyes, antennae, and ultrasensitive legs), it locates the cricket by directional hearing in the same way that humans use stereo processing to determine which nearby car is blaring the offensive music at 140 dB. However, the fly's eardrums — located beneath its head — are only 0.5 mm apart, which, theoretically, is too close to allow "bilateral interaural intensity differences" to be detected at the cricket's chirp frequency of about 5 kHz (which translates into a wavelength of approximately 69 mm).

The secret lies in the fact that the fly's eardrums are connected by a small bridge. The official explanation is that, when a sound is detected in the right ear, the right eardrum vibrates, causing the left eardrum to vibrate out of sync, and vice versa. This back-and-forth vibration of the eardrums creates a difference in pressure between the two ears, which the fly's ganglia and brain quickly compute. Within 50 nanoseconds (1,000 times faster than you can do it), Ormia's brain sends a signal to its muscles and the fly turns toward its target. When a recording of a cricket's chirp is played for the subject fly, it responds quickly and accurately (much more so than a female cricket, which was what the male was actually hoping to attract).

By now, you are probably wondering what this has to do with electronics. The connection is that the fly's audio equipment has inspired a novel design for hearing aids that, within a few years, could perform better and cost much less than existing designs. As stated by NIDCD Director James Battey, Jr., "The biological lessons provided by Ormia's abilities in hyperacute time coding and localization of sound promise to produce strategies for improved nano- or micro-scale directional microphones in hearing aids. Applications of these new principles may improve life for individuals with hearing loss who depend upon hearing aids."

Improvement in Magnetic Refrigeration

The concept of magnetic refrigeration has existed since the 1920s and one scientist (Canadian William Francis Giauque) even won a 1949 Nobel Prize for related work. A magnetic refrigerator could potentially offer better energy efficiency, lower operating costs, the elimination of environmentally hostile coolants, and nearly silent operation. Nevertheless, the concept has never been translated into practical, commercial products and we all still live with the century-old technology of vapor-compression cooling systems.

The situation could change, however, as a result of developments at the National Institute of Standards and Technology (NIST, **www.nist.gov**). An NIST team has discovered that, by adding a small amount (about 1%) of iron to a gadolinium-germanium alloy, its cooling capacity can be increased by 15 to 30%, resulting in, "a much-improved magnetic refrigerant for near-room-temperature appli-

cations." The iron nearly eliminates costly hysteresis effects that otherwise appear during the on-and-off cycling of the applied magnetic field that drives the refrigeration device.

In operation, when exposed to a magnetic field, the gadolinium alloy and other materials heat up as their spinning electrons align with the field, thereby magnetizing the materials and raising their temperatures. When the external field is removed, the materials demagnetize (the electrons revert to a disordered magnetic spin state), and their temperature drops. The two stage process forms the magnetic refrigeration cycle.

Magnetic refrigeration is already a potential contender for specialized applications, such as cooling sensors in spacecraft and the liquification of gases. With additional development, it could be extended to household refrigerators and freezers, dehumidifiers, and air conditioners — which now account for about 25% of residential power use.

Computers and Networking

HP Introduces New Workstations

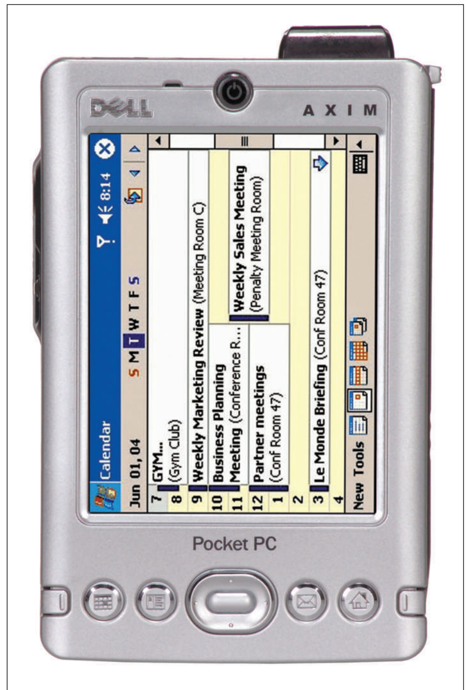
Continuing with now-typical evolutionary — rather than revolutionary — developments in the microcomputer industry, Hewlett-Packard (**www.hp.com**) has introduced three new machines. The HP Workstation xw4200 is the entry level machine aimed at engineers, artists, designers, scientists, and other users who have intense application demands, require large, complex models or data sets, and have multitasking requirements or extensive graphic needs.

The xw4200 features Intel's 925X Express chipset and Pentium 4 processors with Hyper-Threading technology and speeds up to 3.6 GHz with an 800 MHz front-side bus. The new chipset drives the PCI-Express graphics and input/output interface, DDR-2 memory architecture, integrated Serial ATA RAID controller, and — when available — support for future Intel EM64T processors.

Also introduced were the xw6200 and xw8200 models. All support Windows® XP Professional and Red Hat Enterprise Linux WS 3.0 operating systems. The xw4200, xw6200, and xw8200 are priced at $849.00, $1,399.00, and $1,799.00, respectively.

624 MHz Pocket PC

Dell has introduced three new Axim handheld computers that include Intel's PXA270 processors, Windows Mobile® 2003 Second Edition software for Pocket PC, and Bluetooth® wireless technology. Two of the three configurations feature a combination of Bluetooth and WiFi® 802.11b wireless. Bluetooth allows personal area networking with computer systems and Bluetooth-enabled devices such as mobile phones, GPS receivers, keyboards, and other handheld computers. Integrated WiFi enables users to



Dell's Axim handhelds employ Intel's PXA270 processor and are available with wireless technology.

connect wirelessly to the Internet at restaurants and coffee houses, college campuses, sports venues, hotels, airports, and other locations.

Prices start at $199.00 for a non-wireless 312 MHz configuration, $249.00 (after a $30.00 rebate) if you include combination wireless capability, and $349.00 for the 624 MHz model. All three configurations include a built-in secure digital I/O slot, a 3.5 inch transflective TFT color display with 240 x 320 (QVGA) resolution, a headphone jack and improved recorder capability, plus a scroll dial.

The $199.00 and $249.00 configurations come with a travel sync cable, while the $349.00 configuration comes with a sync/recharge cradle with an extra battery charge slot that accommodates either the spare standard battery (950 mAh) or the optional high capacity (1,800 mAh) battery ($99.00). Details are available at **www.dell.com**

Circuits and Devices

High-End MiniDisc Player

Sony's QUALIA® MiniDisc player.

If your bank account has been looking too plush lately, Sony Electronics has a solution in the form of its QUALIA 017 MiniDisc player. According to Sony, "Individually crafted from a solid brass block and perched on a beautifully design charging station, the QUALIA 017 is truly an objets d'art." It's not all good looks and snob appeal, though. The construction is said to provide a more rigid case, which reduces the kind of wear and tear experienced by all portable audio devices.

Included with the player is a set of high quality, low profile ear bud headphones that feature extended bass capability. It has been reported that the headphones can reproduce frequencies up to 100 kHz, which will come in handy if your dog likes to use it. It also comes with a carrying case that employs a magnetic lock and it is available in chrome, silver-plated, or gold-plated finishes. As of this writing, the device was available only by special order, with a base price of $1,900.00.

For an interesting twist on marketing techniques, visit **www.qualia.sony.us/qualia_main.html** where you can view/download a four minute promotional movie that wraps tranquilizer music around a montage of nature scenery and tells you absolutely nothing about the product line. It's impressive and kind of relaxing, really, but I suspect that most of us will still opt for a $29.95 player from Wal-Mart.

Industry and the Profession

Pirated Software Flourishing

According to a study conducted by the research firm International Data Corporation (IDC — **www.idc.com**) and recently released by the Business Software Alliance (BSA — **www.bsa.org**), 36% of all software installed on computers in 2003 was pirated, representing a loss of nearly $29 billion to the software industry. This year's BSA global piracy study incorporated major software market segments, including operating systems, consumer software, and local market software, as well as business software applications.

The study found that, while $80 billion in software was installed on computers worldwide last year, only $51 billion was legally purchased. For its analysis, IDC drew upon world wide data for software and hardware shipments, conducted more than 5,600 interviews in 15 countries, and used its in-country analysts around the globe to evaluate local market conditions. IDC identified the piracy rate and dollar losses by utilizing proprietary IDC models for PC, software, and license shipments by all industry vendors in 86 countries.

Geographically, the piracy rates break down as follows: Eastern Europe, 71%; Western Europe, 36%; Latin America, 63%; Middle Eastern and African nations, 56%, and North America, 23%. Summing it up, BSA President and CEO Robert Holleyman commented, "The fight for strong intellectual property protection and respect for copyrighted works spans the globe and there is much work to be done."

New Computer Project Announced

COLSA Corporation (**www.colsa.com**) and Apple Computer Corporation (**www.apple.com**) have jointly announced the development of one of the largest and most powerful computers in the world. COLSA has contracted with Apple to deliver the components for a supercluster computer system with more than 3,000 processors to its customer, the US Army's Aviation and Missile Research, Development, and Engineering Center (AMRDEC — **www.redstone.army.mil/amrdec**).

The system will consist of 1,566 dual-processor, rack-mountable Xserve G5 units, which employ Apple's 2.0 GHz G5 CPU. COLSA will build, install, test, and operate the system. The supercluster will be employed to model the complex aero-thermodynamics of hypersonic flight, including applications related to missile interceptors and scramjet engine performance. It will offer peak performance of 25 TFLOPs.

At a cost of about $5 million, it compares favorably with Japan's Earth Simulator computer, which offers 40 TFLOPS performance, but costs $350 million. The machine is expected to be operational late this fall. **NV**

Basics For Beginners

Just For Starters

A Tutorial on Diodes

Materials that can conduct current (silver, gold, aluminum, copper, etc.) contain large numbers of loosely held electrons. Their resistance to the flow of current is measured in just a few *millionths* of an ohm per centimeter. Insulators — such as glass, rubber, and plastic — have very few loosely held electrons and their resistance to the flow of current is measured in a few *million* ohms per centimeter.

Semiconductors

As the term implies, semiconductors are not as conductive as metal, nor are they as non-conductive as insulators. The most commonly used materials in semiconductors are germanium and silicon. Germanium, in its pure form, is rated at 60 ohms per centimeter, while silicon is rated at 60,000 ohms per centimeter.

What enables semiconductors to change their state of conductivity is the addition of controlled amounts of impurities. Arsenic and antimony added to the mix will produce what is known as an n-type material because of the negative charge from the excess of free electrons. A p-type junction can be produced with the careful addition of aluminum, gallium, or indium.

P-N Junction

When a p-type junction is made, the electrical equivalent of "holes" or an absence of electrons is set up. An n junction has an excess of electrons. Combining p and n materials and applying negative current results in a diffusing of electrons across the junction is known as diffusion current.

As you can see in Figure 1, a surplus of electrons from the n material penetrate the space-charge region, flow across the junction, and move through the holes to the positive lead. This is known as forward biasing and results in signal being transferred through the diode.

When the current is reversed, the free electrons are drawn to the positive terminal and the holes are attracted to the negative terminal. This is known as reverse biasing and results in no passage of current through the diode. The more reverse biasing is applied to it, the more resistance the diode presents.

Biasing

Like bipolar transistors, diodes do not respond to signals until a threshold voltage is achieved. The biasing level can vary from one diode to another, but most diodes will trigger at about 0.7 volts. Reverse biasing does not have a threshold and a diode starts responding at the first sign of a signal. Since diodes are mostly given the duty of switching non-sinusoidal signals, biasing — for the most part — is not a factor.

Doping

Doping is the name given to the process of adding impurities that enable the diode to respond to current. Different doping procedures can produce different types of diodes.

For example, over-doping can produce something called a tunnel diode.

Tunnel Diodes

A tunnel diode has a high concentration of impurities in both the p and the n sections of the device. The space-charge region is so narrow in this diode that an electrical charge can pass through the device by tunneling, a quantum-mechanical action that produces a negative-resistance region that has the potential of achieving amplification. In circuits where signal intensity is compromised for one reason or another, the tunnel diode can

Figure 1. Combined P and N junctions

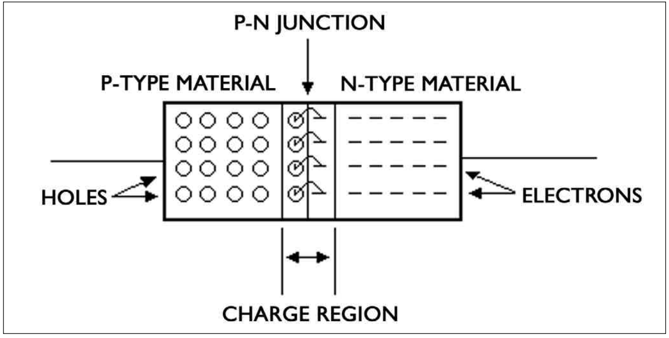
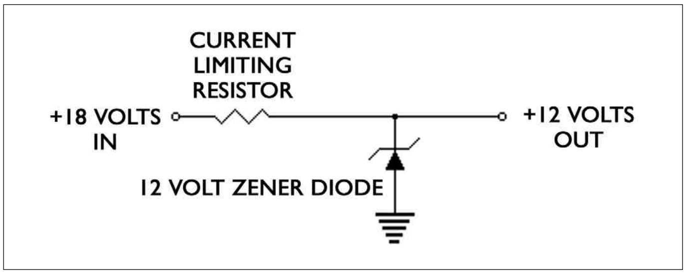


Figure 2. Zener diode operation



help achieve a critical threshold point. Oscillators, pulse generators, and RF energy generation are the areas where the tunnel diode is most applicable.

Zener Diode

Voltage regulation is an important function in modern electronics and the zener diode is designed to do just that. It achieves this in the reverse bias mode. You can see in the diagram (Figure 2) that the zener is wired across a power supply output with the anode lead connected to ground and the cathode lead connected to the supply output.

Like regular diodes, zener devices resist the flow of voltage when reverse biased. The zener, however, is designed to resist the flow of voltage only to a given breakdown point. Anything over the breakdown point will be passed to ground. Acting as a reference source, the zener diode is capable of providing very accurate, constant current loads. Popular cutoff points are 5, 9, and 12 volts to accommodate most power supply requirements.

Varactor

One of the most unusual devices is the varactor or variable-reactance diode. The varactor acts as a voltage sensitive capacitor in series with a resistance. Its use is basically confined to microwave equipment.

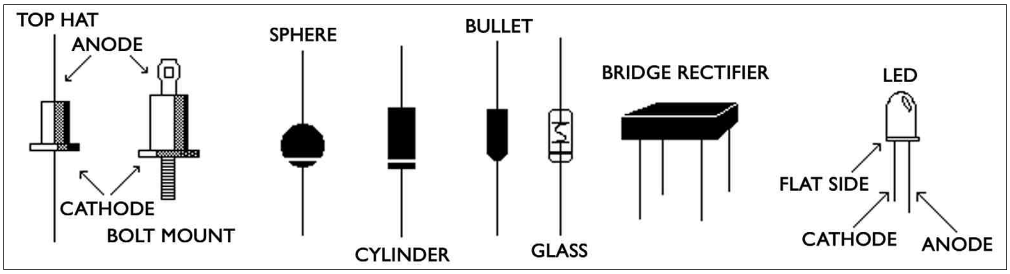


Figure 3. Diode types

Diode Types

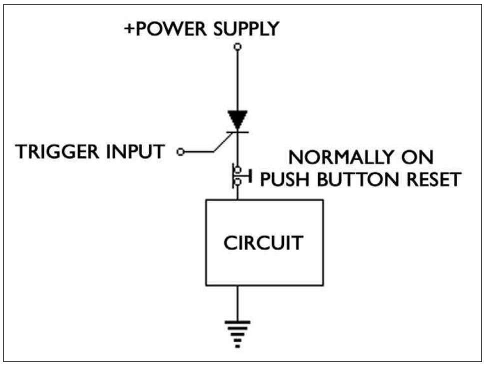
As you can see in the illustration, diodes come in a wide variety of shapes and sizes. The size of a diode will most likely relate to its power handling capacity. Leads are identified as anode and cathode and — on most diodes — polarity is identified by a line on the cathode side, as shown in the diode type illustration (Figure 3).

Your local supplier should have most types in stock. Low level glass diodes, such as the 1N914, are inexpensive (about 10 for $1.00) and widely available. Harder to find diodes can be ordered from supplier catalogs or from the advertisers in *Nuts & Volts*.

SCRs

An SCR (Silicone Controlled Rectifier) is like a diode with an extra lead. The device will not pass current until a pulse is applied to the third lead, which is called a gate. Many switching functions that were formerly controlled

Figure 4. SCR operation



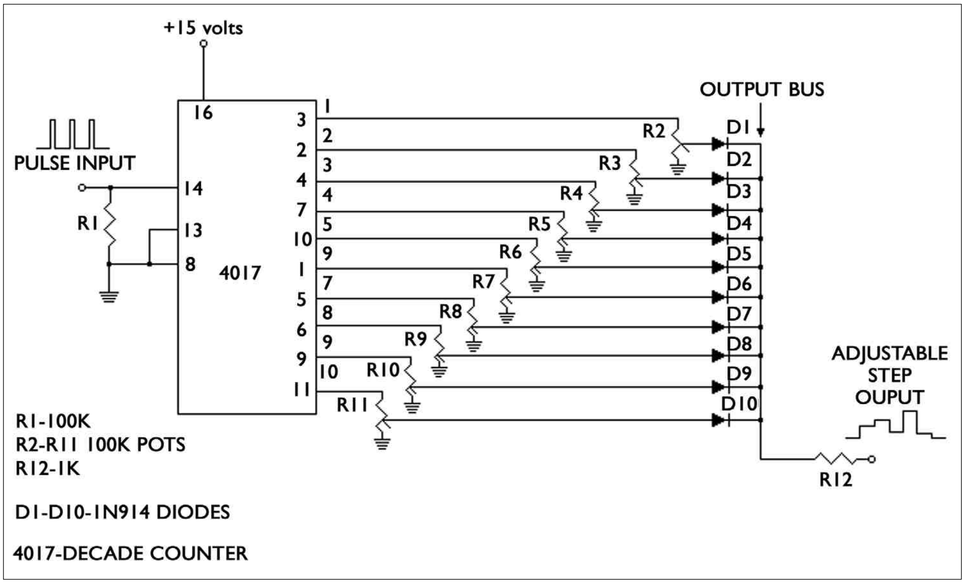


Figure 5. Diode isolated voltage sequencer

by heavy, slow, expensive mechanical relays can be executed by an SCR. Loading problems are another disadvantage of relays that disqualifies them from low current circuits, especially since they need a constant DC input to stay on. Only a brief pulse is necessary to turn on an SCR — and it stays on.

There are two ways to turn it off. The first is by applying a negative pulse to the gate and the second is by disengaging the output load. This second method is popular as a reset in alarm circuits (see Figure 4).

One thing that is necessary when working with SCRs is a constant output load. Most well designed circuits will provide a steady load to maintain the on condition of the SCR. Experimentation will determine whether or not the circuit will sustain an on condition in an SCR controlled situation.

LEDs

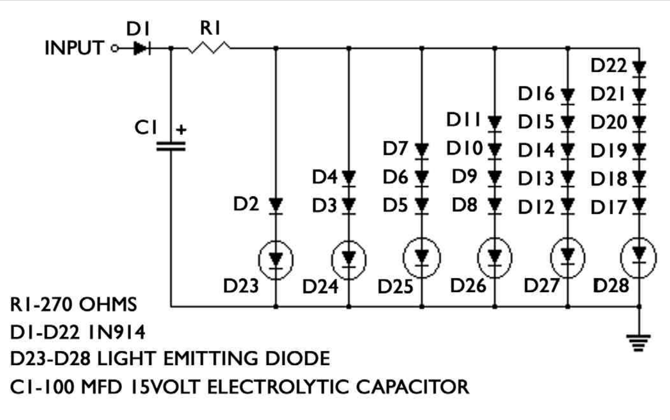
Light Emitting Diodes (LEDs) have been around for quite a while now and almost all electronic devices have one or more. The LED is made by adding metals — such as aluminum, gallium, and indium — to arsenic antimony and phosphors. By changing the ratio of elements, it is possible to vary the color, the amount of infrared radiation, and the brightness greatly from one LED to another.

Wherever you need a visual indication of electrical activity, the LED is the answer. Seven segment displays enable light emitting diodes to indicate letters and numbers and are used in clocks and calculators. Arrays — consisting of several LEDs in a single case — are used to indicate sound levels in recording devices. New products are being developed all the time and amazing devices are finding their ways to the shelves of your suppliers.

Diodes as Isolators

No circuit demonstrates the ability of diodes to pass

Figure 6. Bar graph sound level indicator



and isolate analog signals better than a sequencer. The sequencer in Figure 5 is a 4017 decade counter and it produces a high output (equal to the power supply) at only one of its 10 outputs. The other nine outputs are low and all of the outputs are connected to potentiometers.

When a pulse is fed to pin 14, the counter advances to the next stage. Since only one diode at a time is high, it passes whatever voltage is set by its potentiometer to the output bus. This voltage reverse biases all other diodes, so they become highly resistive and isolate the nine low state outputs.

No interaction between stages will occur because only the voltage at the active stage will be passed to the bus. The result is a manually adjustable staircase wave shape. This circuit is ideally suited to operate voltage controlled oscillators and other electronic music circuits.

Integrated Circuits

Diode elements are etched into ICs to direct signals, prevent false triggering, and stabilize — as well as protect — the circuit. Tunnel diode doping techniques are being researched to increase the efficiency of the new breed of integrated circuits.

Bar Graph Sound Level Indicator

Figure 6 shows how to use diodes in series to set a “trip point.” Twenty-two diodes and six LEDs — along with three resistors and a capacitor — comprise this simple sound level indicator. The input accepts a high level audio signal through D1. As a low level signal rises in amplitude, it meets the biasing threshold of diode D2 and LED D23 lights. When the signal increases beyond the biasing requirement of D3 and D4, LED D24 will light. This process continues down the line to LED D28, as long as the signal level increases.

The new extra bright LEDs work best in this circuit, but, if they are too bright, increase the value of resistor R1.

Because audio levels from music can be transient, signals may occur too quickly to be observed.

Capacitor C1 will help hold the signal long enough for it to be seen. If the capacitor does not hold the signal long enough, try a larger value.

Conclusion

Diodes can help you achieve your circuit goals, whether you want to trigger an alarm, regulate a power supply, or light up a project with LEDs. The diode will point you in the right direction. **NV**

Micro Memories

Shakey — A 1960s Predecessor to Today's Advanced Robotics

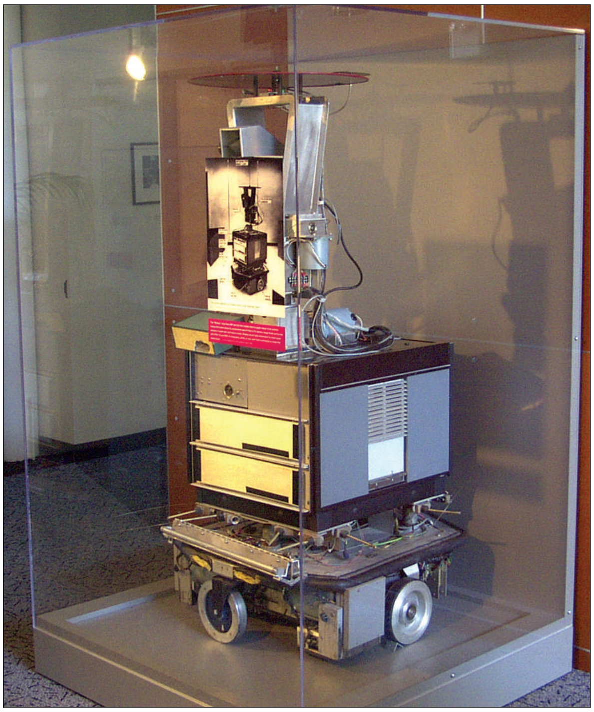
Readers of *Nuts & Volts* and especially *SERVO* — our sister publication — know first hand the remarkable strides that robotics has made in the last 10 years or so.

Yet, as one developer told me, robotics in the first decade of the 21st century are still very much akin to where personal computers were in the mid-1970s. Just as it took decades of experimentation and research to get to the first microcomputer, it has taken robots an equally long gestation period to get to the hobbyist level.

In the 1960s, it required enormous sums of capital just to research robots. There were essentially two groups doing research into robotics: one corporate and the other using government money. Dr. Joseph Engelberger was developing the first robots for automobile assembly lines — technology eagerly purchased by General Motors and, later, by other automobile manufacturers.

Meanwhile, Stanford Research Institute (later known as SRI) — located in Menlo Park, CA — was working with ARPA, the Advanced Research Projects Agency, the central research and development organization for the US government's Department of Defense. (Later, it became officially known as DARPA. The added D stands for Defense. In the late 1960s, it also gave the world Arpanet, the direct forerunner to today's Internet.)

Shakey quietly resides in a Plexiglas case at the Computer History Museum in Mountain View, CA.



The result was a robot eventually known informally — but lovingly — as "Shakey" because of its herky-jerky motions. It became a milestone in robotics technology. As Dr. Richard J. Waldinger of SRI told me, its builders had several objectives for their robot. First, "it was combining wholly different elements in artificial intelligence into a single thing. It did have some English understanding, so you could type commands into Shakey in English and it would type back in English. And then there was vision because it could recognize objects — it had a TV camera so that it could see things and there was work on getting it to tell where the edge of the room was. It could recognize blocks. It could find ramps and other things like that."

Beyond that, one of the goals of the Shakey program was to build a robot that could be given instructions that were less than step-by-step and still have it figure out how to accomplish its tasks. As Waldinger says, its instructions wouldn't say "go here and then go there;" rather, they would say "move this box to this location."

Shakey had no hands, but, as Waldinger says, "it could push boxes with its 'stomach.' It was like a bulldozer; it could push boxes along and the tasks that it could do had to do with moving a box from one place to another and, sometimes, there were things that it had to move out of the way in order to get through a doorway.

In some cases, there were uncertainties; it would think that a box was in place and then someone would secretly move it and it would have to adjust to contingencies that might have interrupted its plans. , it was the first time that a whole bunch of different things were integrated into one system."

The Birth of Shakey

The robot was initially created because Dr. Charles A. Rosen — who led SRI's applied physics lab — had a remarkable idea in 1963. As his colleague, Dr. Nils J. Nilsson, wrote in a 1984 paper, "What would it be like, he wondered, to build a large learning machine whose inputs

would come from television cameras and other sensors and whose outputs would drive effector motors to carry the machine purposefully through its environment?"

Rosen wrote a memo outlining his plans for such a robot or "automaton," as he called it. Then, as Nilsson describes it, "During 1964, we spent a lot of time planning a robot research project and discussing the idea with possible sponsors. As interest in computer science and artificial intelligence grew, we were ready to concede that our robot ought to be equipped with heuristic computer programs, as well as pattern-recognizing learning machines."

Their proposal eventually won funding from ARPA, which sent an informal request to SRI to bid on a research program to develop automatons.

Meet Shakey

Shakey wasn't designed to be an aesthetic knockout — in fact, it was rather ungainly looking. It was several feet tall with a sort of head containing a TV camera and range finder, but that head was attached to a square body containing onboard logic and electronics, a camera control unit, a rubberized "bump detector" for when it came in contact with a wall or other object, and — underneath it all — drive and caster wheels.

Of course, as Dr. Waldinger notes, "There were no personal computers in those days and computers back then were bigger and heavier than you'd want to carry around."

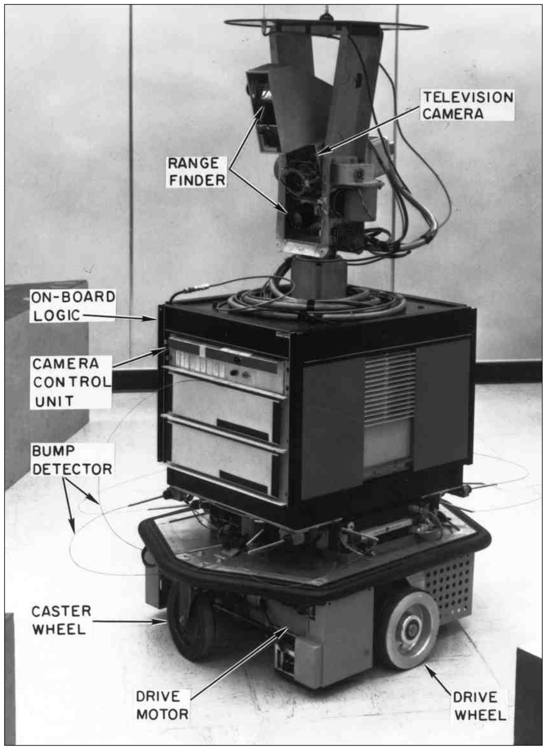
So, Shakey's brains, "were in a larger computer and I think they changed computers from time to time as newer computers came along. I think there was maybe an SDS940 and that might have been replaced by a DEC10. It may have had some things onboard, but not very much." Shakey was connected to them first by cable, "and then, eventually, I think there was a radio link."

Shakey's head combined a television camera and a rangefinder. Unlike a human, his actual brains resided in computers that connected to Shakey via cables, and later, a wireless connection.

Like many prototypes, Waldinger remembers Shakey as being "a very unreliable piece of equipment. First of all, it was very slow and, when it was moving something, it was not very long before something would go wrong.

For example, a lot of things done in the movies were pieced together — it didn't do things all at once; it did a little bit and then it broke and then somebody had to fix it."

SRI made a series of films of Shakey in action. Waldinger notes that, "in the first movie, there was a clock on the wall and you could see by looking at the clock how long things were taking. Actually, sometimes the clock would seem to move backward, because something had been done late one day and then was picked up the next day or maybe



A mid-1960s photo from the Stanford Research Institute diagrams the key features of Shakey.

a couple of days later. So, in subsequent movies, they removed the clock from the wall."

Because Shakey's visual recognition system was far from perfect, it had problems recognizing where the wall ended and where the floor began, so, eventually, SRI painted the baseboard in the room where Shakey ran a darker color to make it obvious where the end of the wall was. If Shakey couldn't see where the end of the room was, it was difficult to orient it.

Six Degrees of Shakey Separation

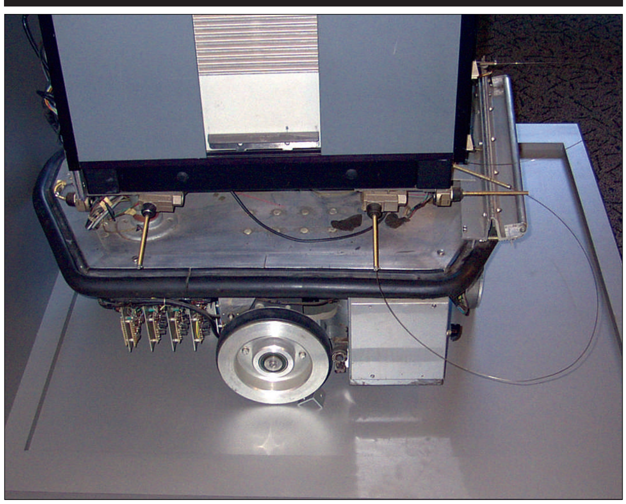
All technology has to begin somewhere and there's a direct link between Shakey and the mobile robots of today. There may be other links as well: Waldinger remembers a presentation given to a group of high-ranking Army officials. One of them asked the men at SRI, "Could you attach a 36-inch blade to that thing?" The response was basically, "I don't see why not!" That may have been the birth of *Robot Wars*, 30 years before its time.

Shakey has another amusing link to today's technology. After DARPA terminated funding on Shakey in 1972, the robot sat in SRI's lobby for several years before eventually ending up in the Computer History Museum in Mountain View, CA (see the July 2001 issue of *Nuts & Volts*).

Nils Nilsson told me that, while Shakey was on display at SRI, various school groups would pass by Shakey, including one with a junior high school student named Bill Gates. Gates later told an associate at Microsoft, "I remember that — I was a junior high school student. I went to SRI and saw Shakey the Robot and it got me all excited about computers."

For a robot that had trouble seeing where it was going, Shakey's legacy definitely went far. **NV**

Shakey used loops of wires as "bump sensors," to alert him to when he was about to hit a wall or other obstacle.



Electronic Theories and Applications From A to Z

Let's Get Technical

Getting More for Less — A First Look at Digital Data Compression

Data compression has been around for a long time. If you've heard the expression, "A picture is worth a thousand words," then you are familiar with the basic principle of data compression: replacing one set of symbols with another, smaller set. A high resolution photograph of an object is a better description than a mere thousand words can evoke.

Today — with practically everything represented by 1s and 0s in some form or another — there is a great need for digital data compression. Why? The answer is time and space. Oh, the Universe is pretty old and really big, but we still want to transmit data from one place to another quickly and we want to use as little storage space as possible.

If you are downloading a file, you want the download to take place as fast as possible. The time required to download the file depends — among other things — on the Internet connection speed and the size of the file. A file size of 2.5 MB will require more time to download than a 245 KB file.

What if, however, there was a way to convert the 2.5 MB file into a 245 KB file? Then, the transfer would take place quickly and the required storage space would be significantly reduced. Even better, after the file is downloaded, the compressed data can be expanded back into the original 2.5 MB.

First, let us think about logical compression. This has to do with the way we represent the data being stored before compression. One method may be better than another, in terms of its built-in logical compression. For example, suppose a programmer has written code to write sensor data to an output file. The programmer used a simple loop of code to write 16-bit ASCII strings of "0" characters and "1" characters, such as:

1001001111101010

which requires 16 bytes of file space.

If the programmer was to spend a little more time in the output loop, then the 16-bit string could be converted into a four-character hexadecimal string, such as:

93EA

saving 12 bytes of file storage space, compressing the output file by 75%, and giving us 4:1 compression. The price we paid was to spend more time on the processing. With the fast computers available today, we can afford the processing time and make use of very complex techniques to obtain good compression rates.

As we just saw, logical compression leads to physical compression. A good example of a logically-compressed code is Morse Code. This code was invented by Samuel Morse in 1844 for use with telegraphs. Letters, digits, and punctuation symbols are defined by dots and dashes in the code. Figure 1 shows the Morse Code for the letters A to Z.

Figure 1. A portion of the Morse Code alphabet.

A	•—	E	•	I	••	M	——	Q	——•—
B	—•••	F	••—•	J	•———	N	—•	R	•—•
C	—•—•	G	——•	K	—•—	O	———	S	•••
D	—••	H	••••	L	•—••	P	•——•	T	—
U	••—	W	•——	Y	—•——				
V	•••—	X	—••—	Z	——••				

Notice that the most frequently-used letter — E — is represented by a single dot. Other popular letters, such as A and I, require only two symbols (dot-dash and dot-dot, respectively). Letters not frequently used, such as X, Q, and Z, contain four symbols each in their codes. Samuel Morse built data compression into his code by designing it so that frequently used letters required the fewest symbols and, thus, were transmitted more quickly than the symbols for less frequently used letters.

You can experiment with digital data compression yourself by working through the following steps to design your own binary version of the Morse Code. In the example described in these steps, a tone generator and speaker are controlled by a single bit. When the bit is high, the speaker emits a tone. When the bit is low, the speaker is quiet.

1. Assign binary patterns to dots and dashes. Since a dash is longer than a

MPEG Audio Layer	Encoder Complexity	Compression	Typical Bit Rate
1	Low	Low (4:1)	384 Kbps
2	Medium	Medium (8:1)	192 Kbps
3	High	High (12:1)	112 Kbps

Table 1. MPEG audio layer differences.

dot (Its tone lasts longer when played), let us use one bit for a dot and two bits for a dash. So, a dot will be a 1 and a dash will be a 11.

2. Assign binary patterns to the symbol, letter, and word spacing. The symbol spacing is the quiet time needed between one dot/dash and another.

For example, in the code for letter A, we have a dot followed by a dash. If we let the symbol spacing be a single bit (equal to 0), we can represent the letter A by the binary pattern 1011. The letter spacing is the quiet time needed between the letters that make up a word or abbreviation. This spacing needs to be longer than the symbol spacing.

Let us use two 0s for the letter spacing. Now the letters OK will encode as 11011011001101011. Last, the quiet time between words must be longer than the quiet time between letters. For this, let us use three 0s. Then, the words HI JIM will encode as 1010101001010001011011011001010011011000.

3. Count the number of bits required to encode a message in the chosen format. For our example, the binary string encoding HI JIM contains 40 bits.

4. Repeat steps 1 through 3, making one or more changes to the binary patterns assigned. Encode the same message as before.

5. Compare the number of bits required for each encoding. If one method is better than another, can you determine why?

You may also change the hardware requirements and see what effect they have on the format and compression of the encoded binary string.

Another logical type of compression is performed while encoding an MP3 audio file. MP3 files get their name from the MPEG Audio Layer 3 specification. MPEG (Moving Picture Experts Group) audio and video are popular encoding methods for creating high quality, low-bit rate multimedia files.

There are three audio layers defined in the MPEG standard. Table 1 lists some of their features. As indicated, Layer 2 is superior to Layer 1, and Layer 3 is superior to Layer 2. Layer 3 requires the most processing power to implement the decompression algorithm; Layer 1 requires the least. Layer 3 encoding did not become popular until the speed of the PC was able to support its calculations. Before the MP3 audio file, the Windows WAV file provided digitized audio for the PC. The WAV file simply stores the sampled audio data without compression.

The Compression column refers to how well the audio information compresses compared to a CD quality, uncompressed bit stream of 1,411,200 bits/second (two 16-bit channels, sampled 44,100 times each second). As indicated in the table, the more processing power you can throw at the compression algorithm, the better your data will compress (to a certain limit).

All three MPEG layers use the same basic techniques for encoding audio and compressing the data. These techniques — called perceptual audio coding and psycho-acoustic compression — utilize knowledge of how humans hear and process sounds to eliminate information that is duplicated or masked out by other sounds.

By eliminating the redundant or unnecessary information, the MP3 file requires less storage space than an uncompressed WAV file for the same audio information. For example, a 30 second WAV file requiring

330 KB of storage was converted into a 220 KB MP3 file. The MP3 file sounds as good as — if not better than — the original WAV file, with the absence of 110 KB of sound information.

Even sampling the analog sound information can be approached from different directions. Using an analog-to-digital converter, you may sample the converter 8,000 times per second, reading an eight-bit sample each time. Thus, a one second audio waveform would require 64,000 bits of storage.

Now, suppose you change the sampling hardware to one that uses a delta modulation method, where the sample can only increase or decrease by a small value each time. (This is the delta.) Then, each sample only requires one bit of storage.

Now, one second of audio only requires 8,000 bits of information. If the delta modulation method does not have significant slope overload losses (signal level changing faster than one delta between samples), it provides a nice, built-in compression over the eight-bit A/D method.

Once the MP3 compressor has thrown away the WAV file's redundant and unnecessary signal information, there is no way to get it back. In this case, it does not matter, since the MP3 format has high quality.

What if we need to have every bit of the original data back when it is uncompressed? If we compress a program file and then uncompress it, every byte in the file has to be correct or the program will not function correctly when the program is executed.

In this case, we need a compression algorithm that is "lossless." The technique used to convert the WAV file to an MP3 file is a "lossy" compression technique, since some of the original data is thrown away.

Okay, so the MP3 audio file is one place where lossy compression may be used to advantage, but where else can we get away with it? We cannot do so in program files, for sure, or even files that contain important information, such as databases, but what about image files?

Browsing the Internet is a widespread activity, awash with images of many shapes and sizes. Web browsers that display graphical images accept two different types of image files: GIF images and JPG (or JPEG) images. GIF stands for Graphics Interchange Format. JPEG stands for Joint Photographic Experts Group. GIF files were created by CompuServe as a method of exchanging graphical information. The features of a .GIF file are as follows:

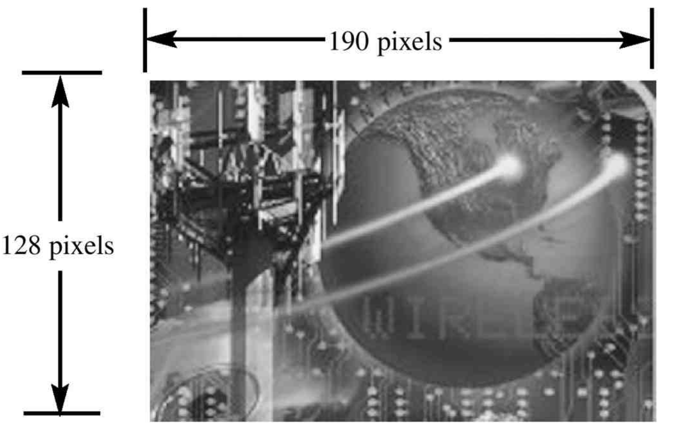


Figure 2. Sample image containing 24,320 pixels.

- Maximum of 256 simultaneous colors
- Lossless compression using LZW (Lempel-Ziv-Welch) algorithm
- Support for animation and transparency built-in
- Interlaced and non-interlaced formats

The quality of the GIF image was kept low so that its file size could be managed. People with dial-up modems for their Internet connection do not want to wait forever for an image to load.

When the GIF image data is decompressed for display purposes, an exact copy of the original data is reproduced, due to the lossless compression used on the original image data.

Compare the properties available in GIF encoding with those of JPG:

- 24-bit color (16,777,216 simultaneous colors with eight bits each for red, green, and blue)
- Lossy compression using the DCT (Discrete Cosine Transform) algorithm on eight-by-eight blocks of pixels
- No animation or transparency available
- Non-interlaced format only

JPG files are preferred over GIF files for their photographic-quality color. In addition, the lossy JPG

Property	GIF Image	JPG Image
Bits / Pixel	8	24
Colors Used	256	20,089
Max Colors	256	16,777,216
File Size	24,557 bytes	10,097 bytes

Table 2. Comparison of the same image saved as a GIF and a JPG.

compression provides better compression, in general, than the lossless compression used in GIF files, with little noticeable effect on image quality. Some images look very poor when saved and viewed as GIF files due to the lack of colors available.

For others, the lossy format of the JPG is unacceptable. This is especially true for medical images, where the actual shade or color of a pixel is important. In the lossy-compressed JPG image, eight-by-eight blocks of pixels have their values adjusted slightly, so the original content of some pixels are lost.

Consider the image shown in Figure 2. The image contains 190 × 128 or 24,320 pixels. Without compression, a total of 24,320 bytes would be needed to store all the eight-bit pixel values for an image of 256 colors and 72,960 bytes would be required for an image with 24-bit pixel values.

Examine Table 2, which shows the results of saving the image in GIF and JPG formats. Both formats require fewer than the 24,320 byte, uncompressed, eight-bit color file size. The JPG compression is clearly superior to the GIF compression; however, the JPG image file requires less than half the space of the GIF image file and only one seventh of the estimated 72,960 bytes for an uncompressed, 24-bit color file. Viewing each image side by side also illustrates why JPEG is the better format for high quality images. The JPG image contains almost 80 times the number of colors as the GIF image.

So, we have seen that there are lossy and lossless compression techniques and that there are applications for both methods.

Next time, we will examine some specific compression techniques, including run-length coding, Huffman coding, the LZW algorithm, and sequence coding (all lossless), as well as the Discrete Cosine Transform (which is used within the JPG's lossy compression algorithm). **NV**

About the Author

James Antonakos is a Professor in the Departments of Electrical Engineering Technology and Computer Studies at Broome Community College. He has over 28 years of experience designing digital and analog circuitry and developing software. He is also the author of numerous textbooks on microprocessors, programming, and microcomputer systems. You may reach him at antonakos_j@sunybroome.edu or visit his website at **www.sunybroome.edu/~antonakos_j**

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FALL SUPER SALE!

ramseykits.com

Expires 10-10-2004

Professional FM Stereo Radio Station

- ✔ **Synthesized 88-108 MHz with no drift**
- ✔ **Built-in mixer - 2 line inputs, 1 mic input**
- ✔ **Line level monitor output**
- ✔ **High power version available for export use**

The all new design of our very popular FM100! Designed new from the ground up, including SMT technology for the best performance ever! Frequency synthesized PLL assures drift-free operation with simple front panel frequency selection. Built-in audio mixer features LED bargraph meters to make setting audio a breeze. The kit includes metal case, whip antenna and built-in 110 volt AC power supply.

FALL SUPER SALE! Expires 10/10/04

FM100B	**Super-Pro FM Stereo Radio Station Kit**	$259.95	~~$269.95~~
FM100BEX	**1 Watt, Export Version, Kit**	$329.95	~~$349.95~~
FM100BWT	**1 Watt, Export Version, Wired & Tested**	$399.95	~~$429.95~~

Professional 40 Watt Power Amplifier

- ✔ **Frequency range 87.5 to 108 MHz**
- ✔ **Variable 1 to 40 watt power output**
- ✔ **Selectable 1W or 5W drive**

At last, the number one requested new product is here! The PA100 is a professional quality FM power amplifier with 30-40 watts output that has variable drive capabilities. With a mere one watt drive you can boost your output up to 30 watts! The output is continuously variable throughout the full range! If you are currently using an FM transmitter that provides more than one watt RF output, no problem! The drive input is selectable for one or five watts to achieve the full rated output! Features a multifunction LED display to show you output power, input drive, VSWR, temperature, and fault conditions. The built-in microprocessor provides AUTOMATIC protection for VSWR, over-drive, and over-temperature. The built-in fan provides a cool 24/7 continuous duty cycle to keep your station on the air!

FALL SUPER SALE! Expires 10/10/04

PA100	**40 Watt FM Power Amplifier, Assembled & Tested**	$549.95	~~$599.95~~

Synthesized Stereo FM Transmitter

- ✔ **Fully synthesized 88-108 MHz for no drift**
- ✔ **Line level inputs and output**
- ✔ **All new design, using SMT technology**

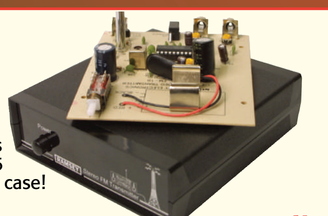
Need professional quality features but can't justify the cost of a commercial FM exciter? The FM25B is the answer! A cut above the rest, the FM25B features a PIC microprocessor for easy frequency programming without the need for look-up tables or complicated formulas! The transmit frequency is easily set using DIP switches; no need for tuning coils or "tweaking" to work with today's 'digital' receivers. Frequency drift is a thing of the past with PLL control making your signal rock solid all the time - just like commercial stations. Kit comes complete with case set, whip antenna, 120 VAC power adapter, 1/8" Stereo to RCA patch cable, and easy assembly instructions - you'll be on the air in just an evening!

FALL SUPER SALE! Expires 10/10/04

FM25B	**Professional Synthesized FM Stereo Transmitter Kit**	$119.95	~~$139.95~~

Tunable FM Stereo Transmitter

- ✔ **Tunable throughout the FM band, 88-108 MHz**
- ✔ **Settable pre-emphasis 50 or 75 µSec for worldwide operation**
- ✔ **Line level inputs with RCA connectors**



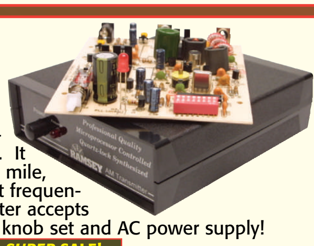
The FM10A has plenty of power and our manual goes into great detail outlining all the aspects of antennas, transmitting range and the FCC rules and regulations. Runs on internal 9V battery, external power from 5 to 15 VDC, or an optional 120 VAC adapter is also available. Includes matching case!

FALL SUPER SALE! Expires 10/10/04

FM10C	**Tunable FM Stereo Transmitter Kit**	$34.95	~~$44.95~~
FMAC	**110VAC Power Supply for FM10A**		$9.95

Professional Synthesized AM Transmitter

- ✔ **Fully frequency synthesized, no frequency drift!**
- ✔ **Ideal for schools**
- ✔ **Microprocessor controlled**



Run your own radio station! The AM25 operates anywhere within the standard AM broadcast band, and is easily set to any clear channel in your area. It is widely used by schools - standard output is 100 mW, with range up to ¼ mile, but is jumper settable for higher output where regulations allow. Broadcast frequency is easily set with dip-switches and is stable without drifting. The transmitter accepts line level input from CD players, tape decks, etc. Includes matching case & knob set and AC power supply!

FALL SUPER SALE! Expires 10/10/04

AM25	**Professional Synthesized AM Transmitter Kit**	$89.95	~~$99.95~~

Tunable AM Transmitter

- ✔ **Tunes the entire 550-1600 KHz AM band**
- ✔ **100 mW output, operates on 9-12 VDC**
- ✔ **Line level input with RCA connector**

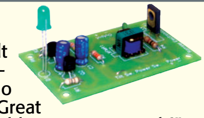
A great first kit, and a really neat AM transmitter! Tunable throughout the entire AM broadcast band. 100 mW output for great range! One of the most popular kits for schools and scouts! Includes matching case for a finished look!

FALL SUPER SALE! Expires 10/10/04

AM1C	**Tunable AM Radio Transmitter Kit**	$29.95	~~$34.95~~
AC125	**110VAC Power Supply for AM1**		$9.95

Mini-Kits... The Building Blocks!

Tickle-Stick



The kit has a pulsing 80 volt tickle output and a mischievous blinking LED. And who can resist a blinking light! Great fun for your desk, "Hey, I told you not to touch!" Runs on 3-6 VDC

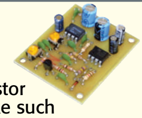
TS4 **Tickle Stick Kit** **$12.95**

Super Snoop Amplifier

Super sensitive amplifier that will pick up a pin drop at 15 feet! Full 2 watts output. Makes a great "big ear" microphone. Runs on 6-15 VDC

BN9 **Super Snoop Amp Kit** **$9.95**

Dripping Faucet



Produces a very pleasant, but obnoxious, repetitive "plink, plink" sound! Learn how a simple transistor oscillator and a 555 timer can make such a sound! Runs on 4-9 VDC.

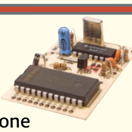
EDF1 **Dripping Faucet Kit** **$9.95**

LED Blinky

Our #1 Mini-Kit for 31 years! Alternately flashes two jumbo red LED's. Great for signs, name badges, model railroading, and more. Runs on 3-15 VDC.

BL1 **LED Blinky Kit** **$7.95**

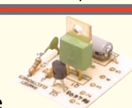
Touch Tone Decoder



Strappable to detect any single DTMF digit. Provides a closure to ground up to 20mA. Connect to any speaker, detector or even a phone line. Runs on 5 VDC.

TT7 **DTMF Decoder Kit** **$24.95**

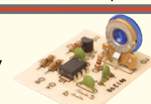
Electronic Siren



Produces the upward and downward wail of a police siren. Produces 5W output, and will drive any speaker! Runs on 6-12 VDC.

SM3 **Electronic Siren Kit** **$7.95**

Universal Timer



Build anything from a time delay to an audio oscillator using the versatile 555 timer chip! Comes with lots of application ideas. Runs on 5-15 VDC.

UT5 **Universal Timer Kit** **$9.95**

Voice Switch

Voice activated (VOX) provides a switched output when it hears a sound. Great for a hands free PTT switch, or to turn on a recorder or light! Runs on 6-12 VDC and drives a 100 mA load.

VS1 **Voice Switch Kit** **$9.95**

Tone Encoder/Decoder

Encodes OR decodes any tone 40 Hz to 5KHz! Add a small cap and it will go as low as 10 Hz! Tunable with a precision 20 turn pot. Runs on 5-12 VDC and will drive any load up to 100 mA.

TD1 **Encoder/Decoder Kit** **$9.95**

RF Preamplifier

Super broadband preamp from 100 KHz to 1000 MHz! Gain is greater than 20dB while noise is less than 4dB! 50-75 ohm input. Runs on 12-15 VDC.

SA7 **RF Preamp Kit** **$19.95**

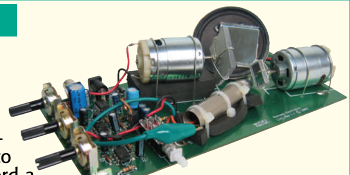
Touch Switch

Touch on, touch off, or momentary touch hold, your choice! Uses CMOS technology. Runs on 6-12 VDC and drives any load up to 100 mA.

TS1 **Touch Switch Kit** **$9.95**

The Neatest Kits!
Where The Fun Always Starts!

Laser Light Show



✔ Audio input modulates pattern!
✔ Adjustable pattern and speed!
✔ Projects neat motorized patterns!
✔ Uses safe plastic mirrors

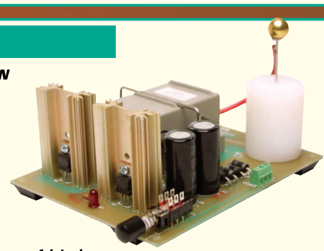
You've probably seen a laser show at concerts or on TV. They're pretty impressive to say the least! Knowing that you can't afford a professional laser display we challenged our engineers to design one that's neat and easy to build, yet inexpensive. Well, the result is the new LLS1 Laser Light Show! This thing is sweet! It utilizes two small motors and a small standard laser pointer as the basics. Then, we gave it variable pattern and speed controls to customize the pattern!

Not enough, you say? How about a line level audio input to modulate the pattern with your CD's or music? You bet! Everything is included, even the small laser pointer. And to make the kit absolutely safe, we even used plastic mirrors instead of glass that could break! Runs on 6-12 VDC or our standard 12VDC AC Adapter (not included). If you're looking for a fun and neat little laser kit, the LLS1 is for you!

FALL SUPER SALE! Expires 10/10/04

LLS1	Laser Light Show Kit	$37.95	~~$44.95~~
AC125	110VAC Power Supply		$9.95

Plasma Generator



✔ Generate 2" sparks to a handheld screw driver!
✔ Light fluorescent tubes without wires!
✔ Up to 25kV @ 20 KHz!

This new kit was conceived by one of our engineers that likes to play with things that can generate large, loud sparks and other frightening devices.

During the process of looking for parts for one of his latest experiments, he discovered how difficult it was to find a fly back transformer that met his requirements. This kit creates very impressive displays, drawing large sparks, and performing lots of high voltage experiments. It can also be used for powering other experiments, let your imagination be your guide!

The high voltage at the terminal won't electrocute you, so it's relatively safe, but it can burn you! So use caution when the power is on!!! Can also be run from 6-16VDC so the output voltage can be directly adjusted. Advanced experimenters only! Not for the faint of heart!

FALL SUPER SALE! Expires 10/10/04

PG13	Plasma Generator Kit	$57.95	~~$64.95~~
PS21	12VAC Output 110VAC Power Supply		$19.95

Ion Generator

✔ Negative ions with a blast of fresh air!
✔ Generates 7.5kV DC negative at 400µA
✔ Steady state DC voltage, not pulsed!

This nifty kit includes a pre-made high voltage ion generator potted for your protection, and probably the best one available for the price.

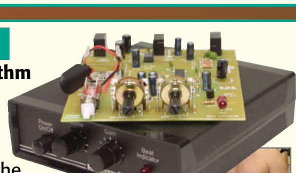
It also includes a neat experiment called an "ion wind generator". This generator works great for pollution removal in small areas (Imagine after Grandpa gets done in the bathroom!), and moves the air through the filter simply by the force of ion repulsion! Learn how modern spacecraft use ions to accelerate through space.

Includes ion power supply, 7 ion wind tubes, and mounting hardware for the ion wind generator. Runs on 12 VDC.

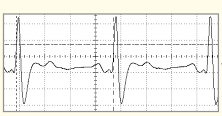
FALL SUPER SALE! Expires 10/10/04

IG7	Ion Generator Kit	$57.95	~~$64.95~~
AC125	110VAC Power Supply		$9.95

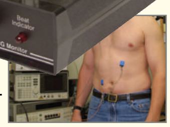
Electrocardiogram Heart Monitor



✔ Visible & audible display of your heart rhythm
✔ Re-usable sensors included!
✔ Monitor output for your scope
✔ Simple & safe 9V battery operation



Enjoy learning about the inner workings of the heart while at the same time covering the stage-by-stage electronic circuit theory used in the kit to monitor it.



The three probe wire pick-ups allow for easy application and experimentation without the cumbersome harness normally associated with ECG monitors. Operates on a standard 9VDC battery. Includes matching case for a great finished look. The ECG1 has become one of our most popular kits with hundreds and hundreds of customers wanting to get "Heart Smart"!

FALL SUPER SALE! Expires 10/10/04

ECG1C	Electrocardiogram Heart Monitor Kit With Case	$39.95	~~$44.95~~
ECG1WT	Factory Assembled & Tested ECG1		$89.95
ECGP10	Replacement Reusable Probe Patches, 10 Pack		$7.95

Electronic Learning Labs

✔ Learn and build!
✔ 130, 300, & 500 In One!
✔ Super comprehensive training manuals!

Whether you want to learn the basics of electricity, the theory of electronics, or advanced digital technology, our lab kits are for you! Starting with our PL130, we give you 130 different electronic projects, together with a comprehensive 162 page learning manual. A great start for the kids...young and old!

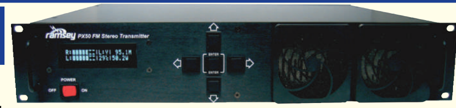
Step up to our PL300, which gives you 300 separate electronic projects along with 165 page learning and theory manual. The PL300 walks you through the learning phase of digital electronics.

If you're looking for the ultimate lab kit, check out our PL500. Includes a whopping 500 separate projects, a 152 page starter course manual, a 78 page advanced course manual, and a 140 page programming course manual! The PL500 covers everything from the basics to digital programming! Learn about electronics and digital technology the fun way and build some neat projects!

FALL SUPER SALE! Expires 10/10/04

PL130	130 In One Learning Lab Kit	$34.95	~~$39.95~~
PL300	300 In One Advanced Learning Lab Kit	$59.95	~~$64.95~~
PL500	500 In One Super Learning Lab Kit		$159.95

50W Stereo FM Transmitter



✔ 50W RF output
✔ Automatic monitoring
✔ Automatic VSWR protection
✔ Automatic temerature protection
✔ Automatic battery backup
✔ FCC CERTIFIED under parts 2, 73, 74

The PX50 is the latest ultra reliable LPFM transmitter from Ramsey. It provide 50 watts of continous duty RF power output with full automatic station monitoring.

The PX50 constantly monitors all of the critical circuits within the transmitter and makes subtle adjustments to various circuit parameters depending upon frequency, temperature, power, audio level, and deviation - in short, it's like having a station engineer constantly monitoring and adjusting on-the-fly! Automatic VSWR protection automatically reduces power output until the VSWR problem is cleared. Likewise, if the power amplifier temperature exceeds 70° C, the transmitter will reduce power output until it cools down below 60° C. You can set automatic *Power Reduction On Error* (VSWR & Temperature errors) to 85%, 75%, 50%, 25% or full disable of the set power. Full power is restored when the error is cleared.

You can also set the *Power Restoration Timer* for the error testing time to match your specific site environment. If the error is cleared within this time, the transmitter is restored to full power for unattended operation! Your station stays on the air, and needless trips to your tower site are eliminated!

Connection is a breeze anywhere in the world. Give it anything from 85-264VAC or 120-370VDC and you're all set. Don't have AC? Simply give it 12-14VDC from a battery source. Connect your stereo audio source and you're on the air! Digital inputs are also provided for RDS and SCA applications!

There has been a lot of confusion, and a lot of concern, regarding equipment requirements for licensed LPFM transmitters. The PX50 is FCC CERTIFIED for PARTS 2, 73, & 74 (ID: PF3PX50). No more worries about your station being forced off the air due to non-compliance!

If you're looking for ultimate reliability in a LPFM stereo transmitter without spending a fortune, the PX50 is your answer! It not only gets you on-the air quickly, but KEEPS you on-the-air! And that's what it's all about.

PX50	50W FM Stereo Transmitter, FCC Certified	$1995.00

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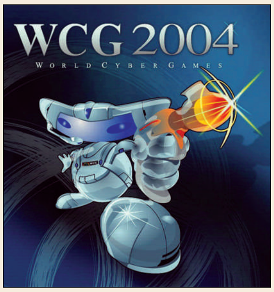
Prices, availability, and specifications are subject to change. Visit www.ramseykits.com for the latest pricing, specials, terms and conditions. Fall Super Sale expires 10-10-2004

Circle #83 on the Reader Service Card.

Game Fair Or Job Fair?

If you're in San Francisco around October 6th, 2004, you might want to take a peek at the goings on at the Bill Graham Civic Auditorium. That's where the World Cyber Games 2004 Grand Final is being held. Representatives from 60 countries will be logging on with their computers, "where cultural barriers are stripped away and international exchange and harmony are promoted." Of course, this is the sort of harmony found on the receiving end of a megawatt pulse rifle aimed from an armored personnel capsule on a high-arc jump.

The WCG 2004 is a video game competition, where the best in the world will attempt to out-drive, out-gun, and out-think their hardware accelerated, texture mapped, and caffeine amped opponents. Official games for both PC and Xbox machines include Counter-Strike: Condition Zero, Unreal Tournament 2004, Project Gotham Racing 2, and Halo. And, in case you think this is just a small event of an under-represented subculture, consider the numbers from the 2003 event: 600,000 competed at the international qualifying events and earned over $1.8 million in prize money from sponsors like Samsung and nVidia.



If I was looking for young people with fast reflexes, acute situation planning skills, and a mastery of computer input devices for the next generation of remotely piloted vehicles, this would be a goldmine. But if you're just a gamer looking to frag some newbies, you can register online: **www.worldcybergames.com**

Power On A Roll

Just get your hands on one of these SolarRoll™ 14 flexible solar panels and you'll see what I mean. Produced by Brunton of Riverton, WY, these lightweight and waterproof panels can be rolled up unto a 3" dia. tube for easy storage between uses, empowering the average gadgeteer to step outside and get some rays. The model 14 produces 14 watts of power — 15.1 volts at 900 mA — and includes adapter cables for several different devices, like satellite phones, digital cameras, and that beanie cap with electric propeller. For larger devices like laptops or basic battery charging, two or more panels can be linked together to increase power output. Though it isn't exactly cheap at $370.00, it is readily available. For more info, visit **www.brunton.com**

O Marks The Spot

Integration is the future of consumer electronics, and the cell phone is ground zero for a myriad of ongoing research. Enter the SpotCode platform, from developers High Energy Magic out of Cambridge in the UK. Looking like a bar code just removed from a spin art machine, a black and white glyph called a Bango Spot may become the "real world hyperlink." The Bango Spot is designed to be read by special software that processes the real-time image from your camera phone. The result of that processing — information on orientation, position, and size — is combined with the decoded numeric identifier and both are transmitted via Bluetooth to a computer in the area, allowing the phone to become a universal pointing device, personal display, and keyboard. Commercial applications abound, where consumer interest could be indicated. Not to mention, walking up to a soda machine and buying a Dr. Pepper. (This earns 9.5 out of 10 on Editor Dan's Clever-o-Meter!) Visit the developers at **www.highenergymagic.com**

Electronics Q&A

In this column, I answer questions about all aspects of electronics, including computer hardware, software, circuits, electronic theory, troubleshooting, and anything else of interest to the hobbyist.

Feel free to participate with your questions, as well as comments and suggestions.

You can reach me at:
TJBYERS@aol.com

What's Up:

Have questions about lightning? I have answers. Two unique 555 timer applications, a low-power headphone amplifier, and a classic car voltage conversion. Plus the usual website suspects and lots of feedback from our readers.

Lightning Physics

Q. During a lightning strike, is the earth considered positive or negative?

Gene Bozek
via Internet

A. Positive. In an electrical storm, the storm cloud is charged like a giant capacitor. The upper portion of the cloud is positive and the lower portion is negative.

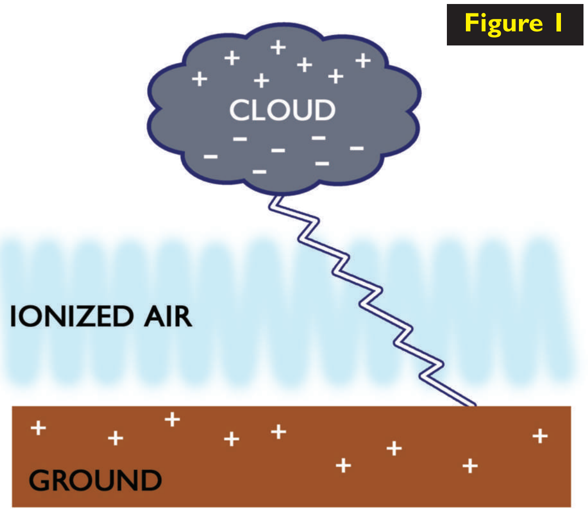
Like all capacitors, an electric field gradient exists between the upper positive and lower negative regions. The strength or intensity of the electric field is directly related to the amount of charge build-up in the cloud. The charge is created by colliding water droplets.

As the collisions continue and the charges at the top and bottom of the cloud increase, the electric field becomes more intense — so intense, in fact, that the electrons at the earth's surface are repelled deeper into the earth by the strong negative charge at the lower portion of the cloud. This repulsion of electrons causes the earth's surface to acquire a strong, positive charge.

The strong electric field also causes the air around the cloud to break down and become ionized (a plasma). A point is reached (usually when the gradient exceeds tens of thousands of volts per inch) where the ionized air begins to act like a conductor. At this point, the ground sends out feelers to the cloud, searching for a path of least resistance. Once that path is established, the cloud-to-earth capacitor discharges in a bright flash of lightning (Figure 1).

Because there's an enormous amount of current in a lightning strike, there's also an enormous amount of heat. (In fact, a bolt of lightning is hotter than the surface of the sun.) The air around the strike becomes super heated — so hot that the air immediate to the strike actually explodes. The explosion creates a sound wave that we call thunder. Some say that lightning strikes like this in the early days of the Earth led to the creation of life.

Figure 1



Cloud to ground strikes are not the only form of lightning, though. There are also ground to cloud (usually originating from a tall structure) and cloud to cloud strikes. These strikes are further defined into normal lightning (discussed above), sheet lightning, heat lightning, ball lightning, red sprite, blue jet, and others that are lesser defined. For more information on lightning, check out **http://science.howstuffworks.com/lightning.htm**

Mapping Lightning

Q. The local TV weather programs sometimes plot the various lightning occurrences as they happen — usually for a three hour period around the state. I've wondered how the lightning strikes are sensed and plotted. Maybe this is done visually from satellite images? Does that work for lightning below the cloud deck? Are there sensing stations that give a bearing to the lightning strike for stations to triangulate on — either radio or visual sensors? I'm just a curious ham operator.

Wally Willhard
Bountiful, UT

A. Satellites are more often used to follow lightning strikes around the world and haven't advanced to the point where they can accurately map local areas like Bountiful, UT (but we're getting there). For that, a network of ground sensors is used. There are two types of sensors commonly used — magnetic direction finders and VHF interferometery.

The National Lightning Detection Network (NLDN), which is operated by Global Atmospherics, Inc., (GAI) in Tucson, AZ (a wholly-owned subsidiary of Vaisala) is a network of more than 130 magnetic direction finders that covers the entire US — more than twice the coverage of existing weather radar networks.

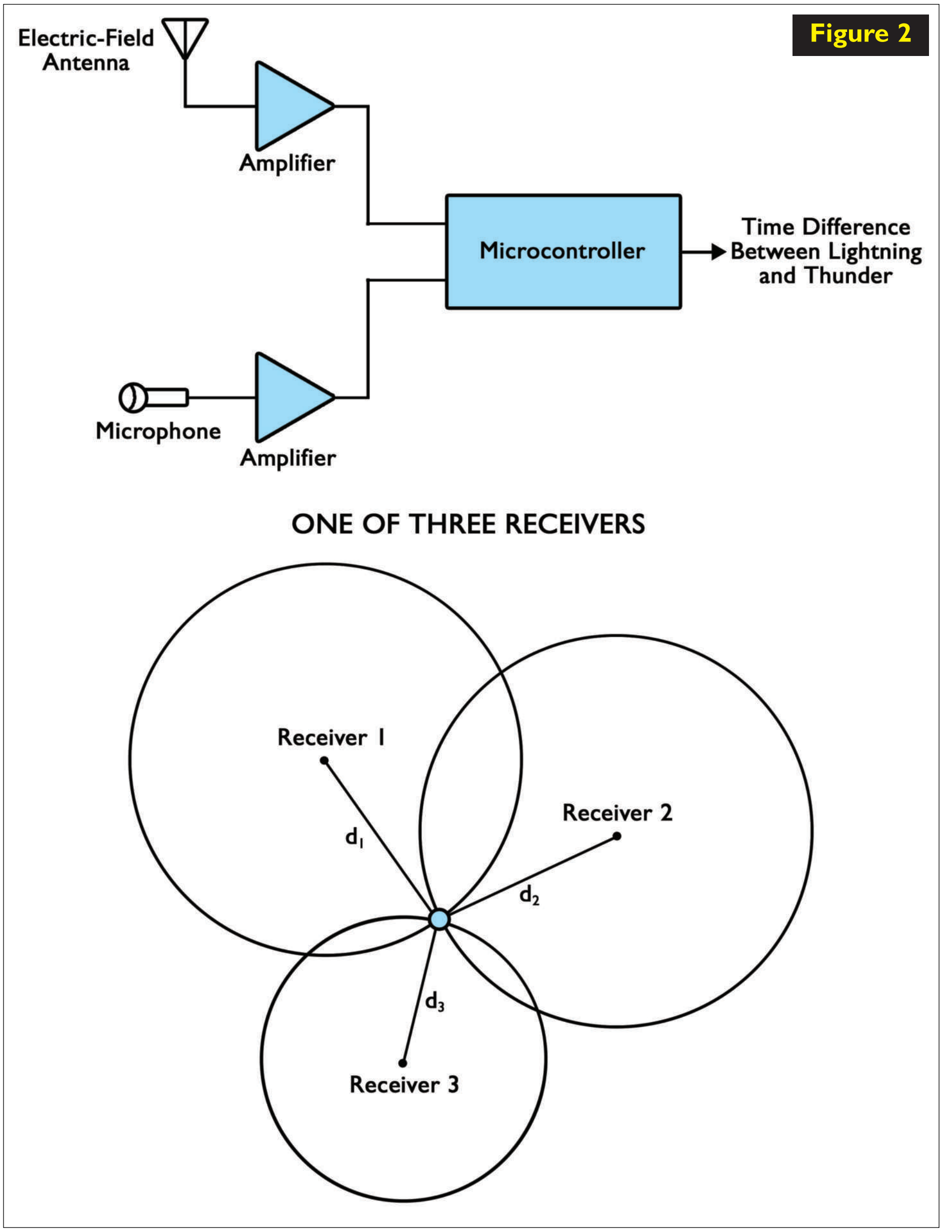
Each direction finder determines the location of a lightning discharge using triangulation and is capable of detecting cloud-to-ground lightning flashes at distances of up to 250 miles and more. Processed information is transmitted to the Network Control Center (NCC) where it's displayed in the form of a grid map showing lightning across the US (**www.lightningstorm.com/tux/jsp/gpg/lex1/mapdisplay_free.jsp**).

Recently, NASA has improved the resolution of the system by adding acoustical measurements to the mix. Although the flash and resulting thunder occur at essentially the same time, light travels at 186,000 miles per second, whereas sound travels at the relative snail pace of one-fifth of a mile in the same time. Thus, the flash — if not obscured by clouds — is seen before the thunder is heard. By counting the seconds between the flash and the thunder and dividing by 5, an estimate of the distance to the strike (in miles) can be made.

In the NASA lightning sensor, a low frequency receiver detects the lightning strike. The leading edge of the electric-field pulse is used to start a timer and the leading edge of the thunder pulse is used to stop the timer. A microcontroller in each receiver transmits the time measured to a processing station, where the times are converted to distances that are used to compute the location of the lightning strike (see Figure 2) to within 12 inches. However, the NASA sensors have to be located within a 30 mile radius of the strike to be accurate — which is no big deal, given that these receivers cost far less to make and install than the GAI direction finders.

You can build a simple, electric-field receiver using the schematic in

Figure 2



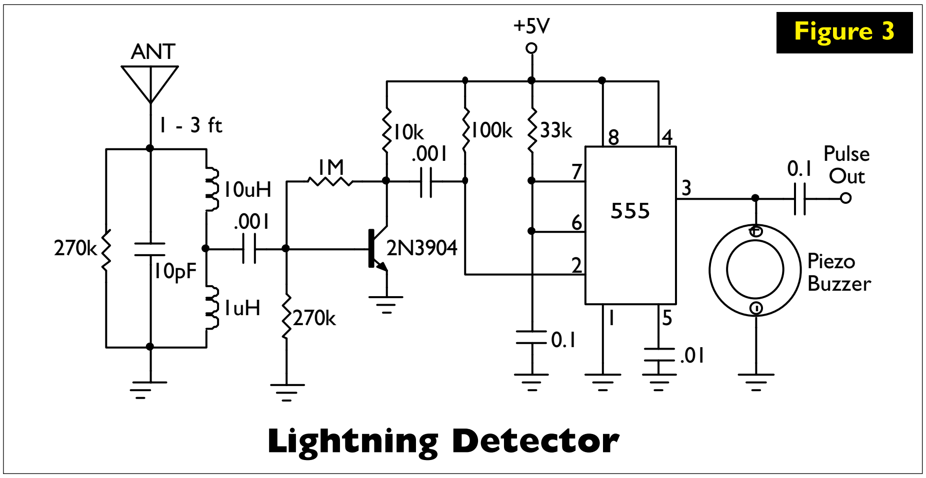


Figure 3. The receiver is tuned to 300 kHz; the sensitivity is adjusted by the length of the antenna in the range of 1 to 3 feet. The longer the antenna, the more sensitive the receiver. The receiver outputs a pulse to the 555 monostable timer when a lightning strike is detected, which causes the piezo buzzer to beep.

A 5 volt Pulse Out signal is also available to start a timer, which you can stop manually when you hear the thunder (or build your own sonic thunder detector). That will give you the distance to the strike. To triangulate, you'll need two or more receivers and a software program (like Excel) to do the math.

Outbuilding Timer

Q. When I want something from my shed, I flip on the light, get what I need, and leave. Of course, more often than not, I forget to shut off the light. Since the shed has no windows, I never notice that the light is on until my next trip to the shed. What I'd like is a timer that would automatically turn the light off after, let's say, 15 minutes.

The switch should work normally if you flip it off before the time expires; otherwise, the timer would take control and turn off the light. Ideally, all the components would fit in a standard electrical utility box, along with the switch. An adjustable time delay would be nice. Any ideas on how I might build such a device?

Dick Baloh
via Internet

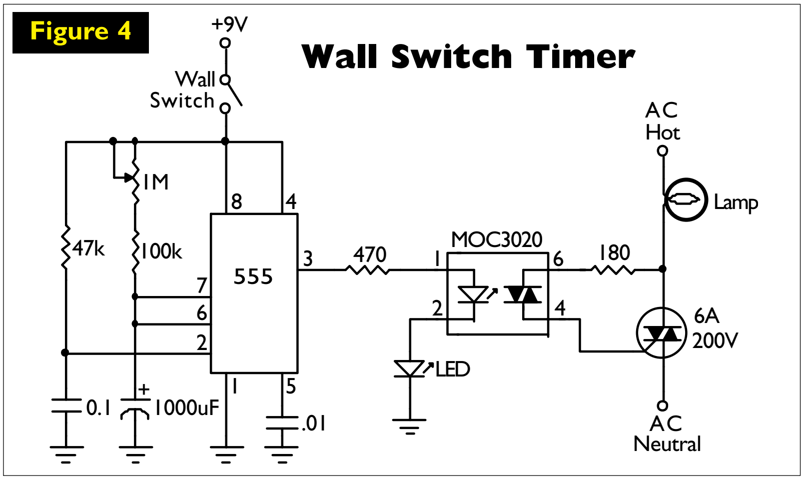
A. My first suggestion is to install a motion detector wall switch, like the one made by Eagle that's available at most hardware stores ($19.95). As long as you are in the shed and moving around, the light remains on. Of course, it has its drawbacks. If you working in an area that has you shielded from the sensor, you could find yourself in the dark. So, I can see why you might want to build your own timer circuit with a predictable off time. For this, a single 555 IC and an optoisolator (Figure 4) will do the trick and the circuit will easily fit into the utility box.

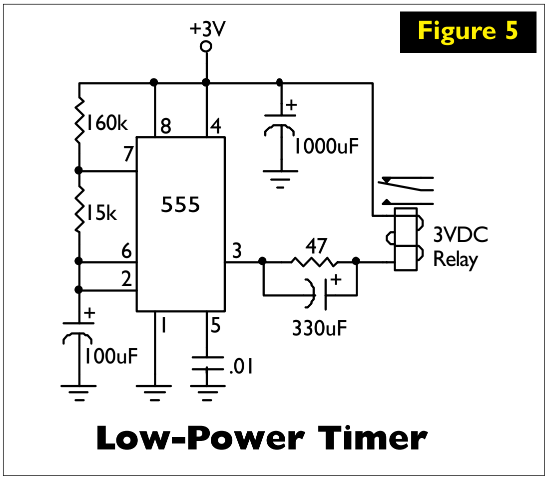
This circuit requires that you remove the wall switch from the AC wiring and use it to switch the 9 volt power source instead. This can be a 9 volt battery, but I'd use a wall-wart because the circuit won't work if the battery goes dead. Turning "on" the light applies voltage to the 555 chip. The 0.1 µF cap on pin 2 forces the trigger input low during power-up and starts the timing period.

The time is adjustable between 2 and 20 minutes using the 1M pot. If you turn off power to the chip before the time expires, the optoisolator's LED goes out and the light turns off. If you forget and leave the switch on, the 555 timer will turn off the optoisolator LED and do the job for you. When building the circuit, be sure to keep the AC mains as far away as possible from the wall switch and 555 circuitry.

Low Voltage 555 Timer

Q. I'd like a 555 timer to actuate a relay (5 VDC @ 150 mA) for 1





second and recycle this event every 13 seconds; therefore, this relay would be engaged for one second for every 13 seconds. However, the entire circuit — relay included — has to operate from 3 volts at 30 mA. (I'd be happier if it would operate even at a lower voltage, such as 1.5 volts.) My problem is that I can't "amplify" the voltage somehow for the relay to be actuated just for 1 second.

Dave
via Internet

A. You can't operate the relay you selected from your power supply. The relay you specify has a coil resistance of 33 ohms (R = 5/0.15 = 33 ohms), which means it takes 90 mA to hold the relay in at 3 volts (I = 3/33 = 90 mA). The answer is to use a 3 volt relay and run it at reduced current, as described in the June 2004 column ("About Relays"). All Electronics (888-826-5432; **www.allelectronics.com**) sells a 3 volt relay (#RLY-623) that should work. It has a coil resistance of 45 ohms and draws 67 mA at 3 volts. In the reduced current mode, it draws about 33 mA, which should be within the capabilities of your power supply. Find the circuit at Figure 5.

The 555 chip has to be a ZSCT1555 from Zetex. Digi-Key (800-344-4539; **www.digikey.com**) has them in stock at \$3.47 each. Unlike the 555 — which has a minimum operating voltage of 4.5 volts — the ZSCT1555 operates over a range of 0.9 to 6 volts. The timing resistors and capacitor are adjusted to your specs, but can be changed to satisfy any duty cycle. When the output goes low, the 330 µF cap charges through the relay coil and engages the relay. After the capacitor is charged, the current flows through the 47 Ω resistor to reduce the relay load. The 1,000 µF cap provides the surge current needed to pull in the relay.

Seeking Clock Chip

Q. I have a kit clock that I built in the early 90s that runs on the MM5314N clock IC from National Semiconductor. I was wondering if you can help me locate a few more of these ICs, in case the one in the clock dies?

Benjamin Rappe
via Internet

A. I have one of those kits, too, so I know your concern. Unfortunately, the MM5314N is almost impossible to find in the US — and for good reason. An eight-bit MCU like the 16F628 can do everything it used to — and more — for less money. Your best bet for a supplier is to look overseas. The following sites claim to have the MM5314N in stock for small quantity purchases.

www.scottele.com

www.computerville.it/tuscania/ik0mmy/ic.htm

www.dicomse.com.ar/

In case you want to do a work-around using present-day MCU/logic chips, here is a pinout of the MM5314N:

http://users.otenet.gr/~athsam/Data_Base/MM5314N_clock_alarm.htm

Cassette To PC

Q. I have a collection of vinyl records and cassette tapes that I would like to copy over to my PC. However, my system is an older, bookshelf stereo with no line-in or line-out jacks. It does have a 1/4 inch headphone jack, though, which I plan to use.

If possible, I would like to listen to the music while copying. How much power is needed by the line-in input of the sound card and how much is needed by the headphones? Do I need a circuit to reduce the headphone signal?

Dean Hansen
New Lisbon, WI

A. I've been monitoring a CD-ROM chat room for a while now and have learned a lot about the transfer of record/tape to a PC's hard disk. One thing I learned is that you can use the headphone jack to directly feed the sound card line input as long as you have a compatible patch cable (1/4" to 3.5 mm stereo, in your case) and adjust the playback system's volume control to provide a solid signal without distortion. No special electronics are required.

All you have to do is tap into this line for monitoring — but it has to be done without pulling down the line with low impedance earphones. What I suggest is a low power headphone amplifier — like the LM4808 — to isolate the headphones from the sound card. The chip is available from Digi-Key. A typical circuit is shown in Figure 6.

I've adjusted the values for 4.5 volt operation — three AA cell batteries, which you can replace with a 5 volt wall-wart. Also, note that I'm using R1 for the volume control. Adjust it to your needs; the lower the resistance, the louder the sound. Of course, you have to supply all the cable breakouts and end connectors. RadioShack should have what you need.

Project Needs PIC Burner

Q. In the April 2004 issue, there is a project entitled "Hand-held Messenger" that seems very interesting to me. However, when I try to download the file that contains the code for the micro (the hex file) from the *Nuts & Volts* website, my computer can't open it. Do I need a special program or software to view this file? I sure would like to see the code, as I am interested in building the project.

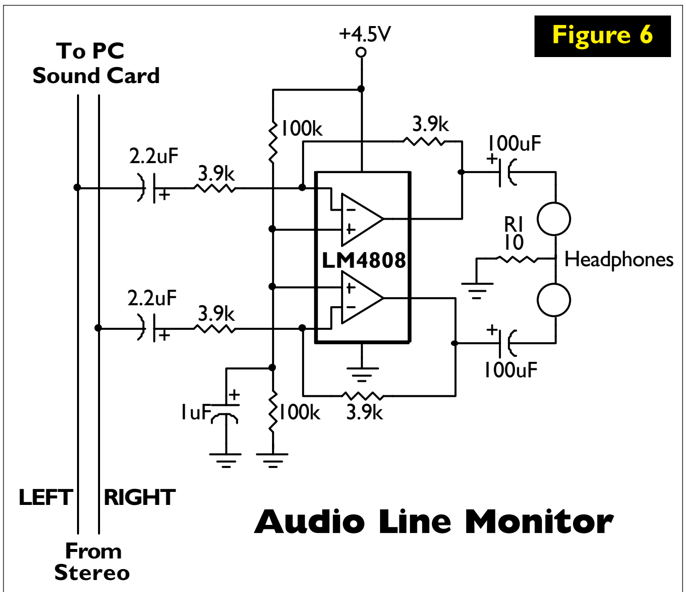
Brian
via Internet

A. When programming a microcontroller (or a CPU, for that matter), you first create a source code file. This file contains all the instructions in computer-ese (probably assembly or Basic) that you can modify — or just read. However, the microcontroller can't read computer-ese. It has to work with binary numbers.

So, the source code is converted into hex format, which the chip understands. This is done using another program, called an assembler or compiler. Once converted to hex, all you can see (using WordPad) are long ASCII strings of 0 through 9, and A through F. At this point, you can't change the program without going back to the source code, making the changes, and generating a new hex file. (Don't write — I know!)

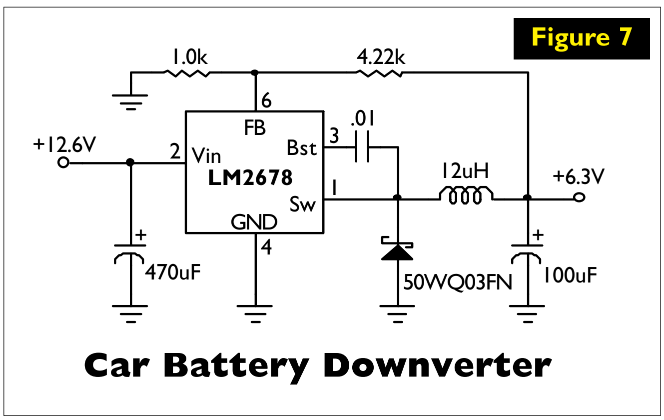
Just having the hex code isn't enough. To get the hex file into the microcontroller, you need a burner. This is a piece of hardware that the controller chip plugs into and connects to the serial, parallel, or USB port of your computer. When you run the burner software, the hex file is transferred to the microcontroller's memory. You're now set. PIC programmers are plentiful and include

Figure 6



Audio Line Monitor

Figure 7



Car Battery Downverter

the popular EPIC from microEngineering Labs (shop around for the best price). Kits and DIY plans for PIC burners are also plentiful.

Be aware, though, that not all PICs are created equal and the HEX code for the "Hand-held Messenger" won't work with just any PIC microprocessor. Make sure you get a burner that supports the PIC16C84 called for in the project. Here's a short list of suppliers:

Dontronics
www.dontronics.com/diyk96.html

EPIC Plus
www.jameco.com

NOPPP
www.covingtoninnovations.com/noppp

PICALL, available from Amazon Electronics
www.picallw.com

Classic Car Conversion

Q. A friend of mind has an old Ford that he restored to excellent condition. Against my advice, he converted the car to 12 volts. The original radio works fine on the 6 volts it was designed for. I can change the six parallel filaments to three sets of two series filaments (7A7s, 7B6, 7B8, 7C5, and 7Y4). I was wondering, if I hit the power transformer with short, 12 volt pulses, would it work as if it was seeing 6 volt vibrator pulses? I want to take this route before designing and building a 60 watt switching power supply.

Merlin Baker
via Internet

A. When I converted my '55 Ford to 12 volts, I used a 1 ohm, 50 watt resistor in series with the hot lead of the 6 volt radio. If you remember the cars of that era, the resistor served double duty by dropping the voltage from 12 to 6 — and heating up the cabin's drafty interior. (Car heaters in those days left a lot to be desired.)

If you'd rather not waste the power, you can build a simple, step-down converter using an LM2678 switching regulator (Figure 7). The circuit was created using National Semiconductor's Webench online design software (**www.national.com/appinfo/power/webench/**). The only critical component is the inductor, which must be rated at 12 µH at 5.5 amps, like the PM2120-120K from JW Miller (Digi-Key #M6184-ND).

Protecting Projection Lamps

Q. Can you provide a circuit to slowly power-up projection lamps in video and movie projectors? These high wattage lamps are expensive and short lived; I would bet a slow turn on would extend the life of the lamps by limiting inrush currents.

Mike
via Internet

A. I assume you are talking about tungsten filament lamps and not the halogen or metal halide versions. The answer is an NTC thermistor. This thermistor starts out with a high resistance that decreases as it heats up from current flow. You can buy them from Digi-Key for under $3.00. The trick is to match the thermistor to the lamp using a rather intricate formula.

To spare you the calculations, I've assembled a table for a few of the most popular lamps. If you don't find your lamp listed, cross it to the voltage and wattage columns to find the inrush thermistor that's right for you. The thermistor should be inserted between the fan and the bulb so that it doesn't limit the fan's cooling air.

Lamp Type	Lamp Volts	Lamp Watts	Lamp Amps	GE Thermistor Model Number	Cold Ohms	Hot Ohms
CLS	120	300	2.5	CL-80	47	0.6
CZA	120	500	4.2	CL-50	7	0.13
CZX	120	500	4.2	CL-50	7	0.13
DDB	120	750	3.6	CL-30	2.5	0.09
ELH	120	300	2.5	CL-80	47	0.6
EXR	82	300	3.7	CL-70	16	0.3
EHJ	24	250	10.4	CL-11	0.7	0.03

Inrush Thermistor Selection Guide

Thanks ... For Nothing!

Q. Some time ago, I requested a scramble/descramble diagram for my 2.4 GHz wireless video camera, but you've entirely ignored my request.

Then, I really wanted an USB trans-receiver with an USB module from **www.linxtechnologies.com** They are actually a *Nuts & Volts* advertiser. So much for helping them increase their sales by featuring a diagram with their USB module! Are they aware of your help in not helping them sell such modules — especially when they indirectly sign your pay check?! Once again, you ignored my request. Maybe other readers like me would have been interested in building such a project. Have you thought of that?

Then, I requested a self-powered timer for an auto ceramic heater (I even sent you a JPEG photo of the heater) to heat up inside a coil and

then run inside a fan, based on a self-timer. Yet again, you ignored my request!

Now, I have this audio frequency amplifier (Please, don't ask me what it's for!) with all the parts for it, but I've forgotten which part goes where. Can you please help me find the accurate values for caps and resistors from the parts list given. My JPEG image doesn't contain viruses!

D. Zillbermann
via Internet

A. I never ignored your requests and even responded to at least one via Email. The problem is that your questions either require more page space than this column affords or that they are too ambiguous or application specific. As for the Linx Technologies question, did you ever check their website? It has your answers.

If other readers feel like Mr. Zillbermann — in that I'm ignoring you — please realize that I receive more questions per month than I can possibly publish. I have to select those questions that appeal to the greater audience. If your question has to be bumped, I do my best to Email you the answer or flip it over to the Tech Forum. Be aware, though, I can't answer a question that takes all of my time or uses up my month's allotment of ink. For that, we have feature articles. So, don't expect me to build your science project or write your thesis.

Hopefully, I will soon have a *Nuts & Volts* "Q & A" web page for those spill-over questions that didn't make the cut for the magazine, but need answering. Stay tuned.

MAILBAG

Dear TJ,

I have been rummaging through my back copies of *Nuts & Volts*, looking for a schematic that you might have been a part of. In doing so, I noted a Mailbag entry in the October 2003 issue from Joseph Wilson suggesting that a particular Heath site did not exist.

Being old enough to have built these kits, I looked for the site and found it at **www.circuitarchive.fsnet.co.uk/heath.htm** (It may take a few tries to access the site; it is available intermittently.) The URL in the magazine left out FSNET.

Plus, in surfing around, I hit upon this site for Heath Robot owners (I have a Hero Jr.): **http://hero.dsavage.net**

Richard Ober
Baton Rouge, LA

*Also try **http://ww_heco.home.mindspring.com/** It keeps better track of the moving Heath websites than I can.*

— TJ

Dear TJ,

Regarding the February 2004 issue, the concept of a 42 volt system (actually 36 volts) is not really new. Back in the 1920s and 1930s, 36 volt lighting systems were used in many railway passenger cars and in rural America where there were, as yet, no commercial power lines. The lamps were designed to operate at 32 volts and looked like ordinary household lamps with the standard Edison screw base and fitted ordinary 110 volt-type sockets. This concept was wonderful for its time.

While it's true that a higher voltage system in an automobile will allow smaller and lighter wiring to be used, there is a potential problem. The wire used on a 36 volt system may need only 1/3 the cross-sectional area of the equivalent 12 volt system, but — in Canada and the northern US — this thinner wire can be susceptible to disruptive corrosion caused by road salt used in the winter to clear the roads.

The problem with corrosion usually is not along the length of the wire, which is insulated, but at the point the wire terminates, where the copper is exposed. Unless the auto makers take much greater care in design and installation to protect these smaller wires than they currently do, there will be a rash of various kinds of automotive electrical system failures long before their time.

Ernie Moore
Nepean, Ontario

Dear TJ,

Your discussion of battery arrangements in the April 2004 issue

brings back a memory from the 50s. There were many small sized communities in which telephone service was provided by manual switchboards operated by independent telephone companies. I was employed by a telecom manufacturer to convert these communities to dial operation.

At one site, our customer (the local phone company) had arranged for Bell Systems to provide some inter-connecting arrangements to other exchanges. The installation of their equipment was to be concurrent with ours. At one point, I was asked where they could pick off 24 volts for their vacuum tube equipment. Our power source consisted of 23 lead-acid cells — 48 volts total. At the direction of the TELCO engineer, I tapped the battery midway and created a distribution point on our panel.

I quickly found I could either boil the water out of half the battery or let the other half go flat. Perhaps the engineer should have known better; I certainly never suspected. Fortunately, the 24 volt load was quite steady. So, I mounted a number of sockets on a piece of crating lumber and screwed in 100 watt light bulbs until the loads were balanced — problem solved.

I went on to another assignment, but had an occasion to revisit the site during an evening hour some months later, only to find an eerie glow of 115 volt bulbs still running off the 24 volt bank. It was not the kind of jury-rig I expected to remain indefinitely.

John S. Young
Scottsdale, AZ

Cool Websites!

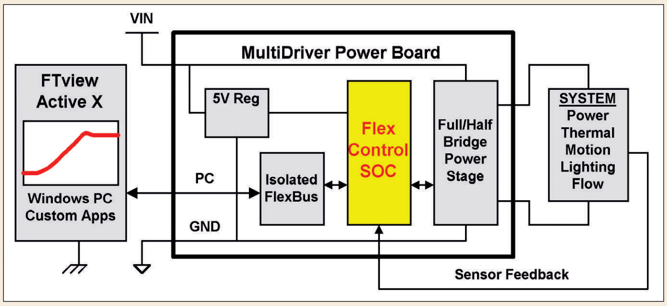
National Semiconductor has offered its popular Webench online simulator for power supply design for several years (see "Classic Car Conversion" above). The company has now broadened the scope of its online tools with "Amplifiers Made Simple." Use it to design your next op-amp application.
www.national.com/appinfo/amps/

Need to kill some time? Try this fun puzzle.
www.johnrausch.com/SlidingBlockPuzzles/nooff.htm

The Universe began not with a bang, but with a low moan — building to a roar that gave way to a deafening hiss. Hear it here.
www.newscientist.com/news/news.jsp?id=ns99995092

Tired of waiting for Adobe's Acrobat Reader to load? The "Adobe Reader SpeedUp" is a small utility that fixes that.
www.tnk-bootblock.co.uk/prods/misc/index.php

DIGITAL POWER CONTROLLER SPEEDS PRODUCT DEVELOPMENT



The versatile power, control, and data interfaces of the MultiDriver™ Board save valuable time by providing an integrated system for digital controller development. Typical applications include power, thermal, motion, lighting, and flow control for industrial and educational purposes. The switching power stage accepts 12 V to 48 V supplies and provides a 6 A half-bridge or 3 A full-bridge output current. Protection features include current limit and thermal shutdown, as well as filters and clamping on a split ground plane. FlexController™ SOC allows quick verification of control algorithms through the PC with free FTview™ software.

The 28-pin DIP controller socket also accepts PIC microchips and provides an In-Circuit-Debugger connection. Data communication is through the FlexBus™ isolated multi-drop serial bus that eliminates line drops and ground noise from measurements, provides protection from power transients, and enables operation at voltages not possible with other systems. The data bus is port-powered, four-device addressable, and compatible with common USB to serial converters for maximum flexibility.

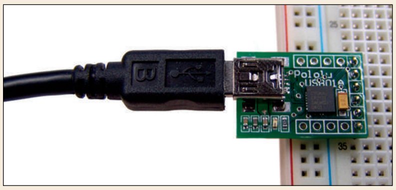
Flextek's product manual provides application notes with schematics and code examples. The board is 2.3 x 3.0 x 0.9 inches with convenient screw terminal connectors. The MultiDriver Board FCMD010 is available now from Flextek Electronics for $79.50.

For more information, contact:

FLEXTEK
Web: **www.flex-tek.com**

Circle #54 on the Reader Service Card.

POLOLU USB-TO-SERIAL ADAPTER



Pololu introduces their new USB-to-serial adapter for connecting microcontroller-based projects to personal computers. The diminutive unit measures under 1.0" x 0.7" including its connector, making it perfect for projects where space is a premium. For quick prototyping, the simple layout of the ground, transmit, and receive lines allows for easy mounting that takes up as little as four breadboard rows.

The USB adapter's drivers make it look like a standard serial port to the operating system.

Therefore, the adapter can be used with existing software — such as servo controller interface programs — that are designed for traditional serial ports. Unlike most USB-to-serial adapters that require an additional RS-232-to-TTL converter, the Pololu USB adapter uses 3.3 V signal levels that can be connected directly to microcontrollers running at up to 5 V.

The adapter is compatible with USB 2.0 standards and allows baud rates of up to 921.6 kbps. Support is initially available for Windows 98 through XP; Mac and Linux support will follow shortly.

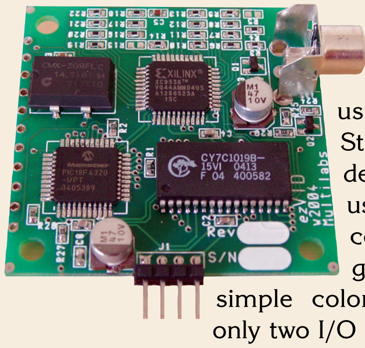
With the trend toward removing serial ports from new computers, the Pololu USB-to-serial adapter provides one of the most economical, small, and simple solutions to the common problem of interfacing small projects to PCs. The price for one unit is $23.00 with free shipping in the US.

For more information, contact:

POLOLU CORPORATION
6000 S. Eastern Ave., Suite 5-E
Las Vegas, NV 89119
Tel: **1-877-7-POLOLU** or **(702) 262-6648**
Fax: **(702) 262-6894**
Email: **www@pololu.com**
Website: **www.pololu.com**

Circle #33 on the Reader Service Card.

*ez*VID SERIAL VIDEO MODULE



The *ez*VID serial video module is a simple video card for use with microcontrollers, Stamp modules, and similar devices. The module makes use of an onboard microcontroller and video signal generating chip to allow simple color video generation with only two I/O lines.

The easy-to-use ezVID commands allow placement of any built-in or user defined character anywhere on the screen in any one of 14 colors; it also allows the user to define up to 256 custom characters, change the background color to any one of 14 colors, clear the entire screen to any one of 14 colors, or reset the system for a

clean start. The pixel resolution of the screen is 188 by 254.

The *ez*VID comes in a simple to use 2" x 2" SIP module that has four mounting holes for secure placement in your project. A four-pin header is provided for easy connection to your project in order to supply power and access the TTL level asynchronous serial data lines. It also comes with a standard RCA style jack for the video output.

The *ez*VID sells for $59.95 and is available through the Multilabs website. It is only available in NTSC.

For more information, contact:

MULTILABS
Lake Forest, CA
Email: **support@multilabs.net**
Web: **www.multilabs.net**

Circle #61 on the Reader Service Card.

GPRS/GSM APPLICATION KIT

Z-World has now released the GPRS/GSM Application Kit. The kit will allow machines the ability to notify a user when they need servicing, have their settings changed from anywhere in the world, upload data wirelessly, send commands from one machine to another, and send vehicle location/conditions via Email. The GPRS/GSM Application Kit is designed to integrate embedded controls with wireless GPRS/GSM communication applications.

Z-World's GPRS/GSM Application Kit provides all the necessary tools to sample and develop applications that combine a Rabbit-based control device with a GSM/GPRS modem, manufactured by Enfora, Inc. The libraries and sample programs allow a device connected to the cellular network to send SMS (text) messages to a RabbitCore module (RCM) that can interpret messages as commands and, in turn, execute control functions. The RCM can also send/receive GPRS Email wirelessly to/from any PC, GSM device, or cell phone. The LCD/keypad module included in the GPRS/GSM Application Kit incorporates a menu system that provides for an easy interface to read or send text messages and Email.

Kit applications include, but are not limited to: wireless automation and control, alarm and notification systems, remote monitoring, data and event logging, machine communication, FTP (File Transfer Protocol) uploading, Telnet, Email, and text messaging communications.

The GPRS/GSM Application Kit includes Z-World's Dynamic CTM integrated development software with royalty-free TCP/IP stack and PPP module, along with a quad band wireless modem and all supporting embedded system hardware.

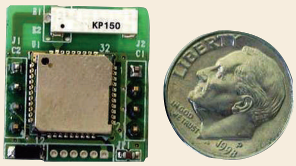
GPRS/GSM Application Kits are available to ship immediately with a price of $649.00.

For more information, contact:

Z-WORLD
2900 Spafford St.
Davis, CA 95616
530-757-3737 Fax: **530-757-3792**
Email: **zworld@zworld.com**
Web: **www.zworld.com**

Circle #85 on the Reader Service Card.

THE NEW BLUETOOTH OEM



PROMI-ESD-02 is an OEM board type of the Promi-SD, Class 2 Bluetooth version. This unit is easy to use and can be embedded in applications, including virtually any type of machinery that requires a wireless, serial communication link. It is long range, easy to install, low cost, and provides point-to-point connection without RS232 cables. Additional features include:

- Class 2 output power: 2.5 mW (4 dBm)
- 3.3 VDC power supply
- Integrated antenna on the board with setup software and manual on CD
- Output interface UART
- Compliant Bluetooth spec. v 1.12
- Transmission power class 2 (max. 4 dBm)
- Dimensions 18 x 20 mm

For more information, contact:

LEMOS INTERNATIONAL CO., INC.
1305 Post Rd. #305
Fairfield, CT 06824
Email: **sales@lemosint.com**
Web: **www.lemosint.com**

Circle #97 on the Reader Service Card.

LANDMARK LR SERIES EXPANDS TO EUROPEAN FREQUENCIES

Linx announces the newest member of the LR Receiver Series of RF modules. The 433 MHz LR receiver interfaces to virtually any data source, including microcontrollers and decoder chips, making them ideal for applications such as remote control, keyless entry, and periodic data transfer. Capable of operating at distances in excess of 3,000 feet, LR receivers deliver 5-10 times greater range than previous solutions. They are also the lowest in cost of any Linx receiver product.

The modules operate over a 2.7-5.2 VDC range and feature low power consumption, wide operational temperature range, adjustable transmitter power, and a receiver sensitivity in excess of -115 dBm. A precision, crystal-locked PLL architecture allows for transparent data transfer at rates of up to 10 kbps. No external components are required (except an antenna), allowing for easy design integration — even by engineers without previous RF experience.

LR series modules are designed for regulatory compliance and interference immunity and are available in frequencies suitable for both domestic and export wireless applications. The modules are housed in a tiny SMD package that is footprint compatible with the popular Linx LC-S receiver, allowing existing customers an instant path to improved range and lower cost.

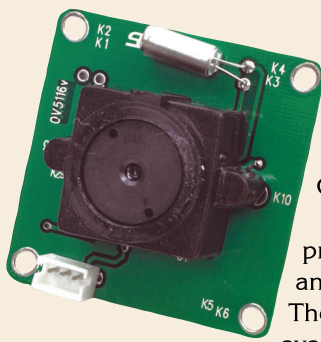
433 MHz LR receivers are in production and priced at approximately $6.78 in volume production quantities.

For more information, contact:

LINX TECHNOLOGIES, INC.
575 SE Ashley Pl.
Grants Pass, OR 97526
Tel: **800-736-6677**
Web: **www.linxtechnologies.com**

Circle #100 on the Reader Service Card.

LATEST GEN/CMOS CAMERA



SUPERCIRCUITS of Liberty Hill, TX has released the new PC300 camera series, which incorporates the latest layered CMOS imaging technology.

The PC300 series cameras produce 280 lines of resolution and a low light rating of 1 lux. The PC300 series cameras are available with two different lens options, a micro lens measuring 0.5 inches in diameter offering a 35 degree field of view and a covert pinhole lens option. The covert pinhole lens needs only a 1/16" inch unobstructed opening to obtain a 25 degree field of view. The PC300 series is also flexible when it comes to power. It can operate between 7 to 14 volts and draws less than 10 milliamps.

The combined performance of this camera makes it great for a variety of scientific, robotic, and security applications. The PC300 series is being introduced at a ground-breaking low price of $11.95, making it within reach for many applications.

For more information, contact:

SUPERCIRCUITS
One Supercircuits Plaza
Liberty Hill, TX 78642
800-335-9777 Fax: **866-267-9777**
Web: **www.supercircuits.com**

Circle #33 on the Reader Service Card.

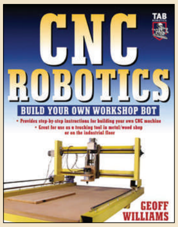
Selected Titles for the Electronics Hobbyist and Technician—

The *Nuts & Volts* Hobbyist Bookstore

Robotics

CNC Robotics

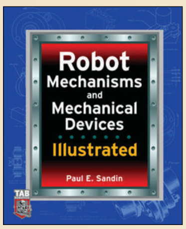
by Geoff Williams



Written by an accomplished workshop bot designer/builder, *CNC Robotics* gives you step-by-step, illustrated directions for designing, constructing, and testing a fully functional CNC robot that saves you 80% of the price of an off-the-shelf bot — and can be customized to suit your purposes exactly because you designed it. **$34.95**

Robot Mechanisms and Mechanical Devices Illustrated

by Paul Sandin

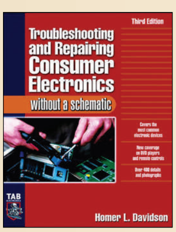


Both hobbyists and professionals will treasure this unique and distinctive sourcebook — the most thorough and thoroughly explained compendium of robot mechanisms and devices ever assembled. Written and illustrated specifically for people fascinated with mobile robots, *Robot Mechanisms and Mechanical Devices Illustrated* offers a one-stop source for everything needed for the mechanical design of state-of-the-art mobile bots. Written by a leading designer of robots used at the horizon of mobile robotics, this resource offers a collection of both new and classic robotic mechanisms and devices unmatched in scope — from such high-level sources as the mechanical engineers' mainstay, *Mechanisms and Mechanical Devices Illustrated*. Paul Sandin's superlative reference also brings you new robotic mechanisms and devices that have never before been collected! **$39.95**

Electronics

Troubleshooting & Repairing Consumer Electronics Without a Schematic

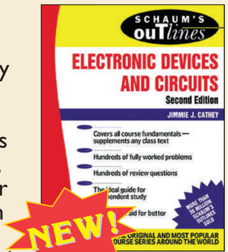
by Homer Davidson



In this book, Homer Davidson gives you hands-on, illustrated guidance on how to troubleshoot and repair a wide range of electronic products — when you can't get your hands on the schematic diagrams. He shows you how to diagnose and solve circuit and mechanical problems in car stereos, cassette players, CD players, VCRs, TVs and TV/VCR combos, DVD players, power supplies, remote controls, and more. **$34.95**

Schaum's Outline of Electronic Devices and Circuits Second Edition

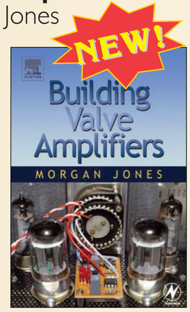
by Jim Cathey



This updated version of its internationally popular predecessor provides introductory problem-solving text for understanding fundamental concepts of electronic devices, their design, and their circuitry. Providing an interface with Pspice (the most widely used program in electronics), new key features include a new chapter presenting the basics of switched mode power supplies, 31 new examples, and 23 PS solved problems. **$16.95**

Building Valve Amplifiers

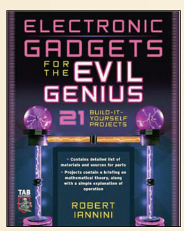
by Morgan Jones



Building Valve Amplifiers is a unique hands-on guide for anyone working with tube audio equipment — as an electronics experimenter, audiophile, or audio engineer. Particular attention has been paid to answering questions commonly asked by newcomers to the world of the vacuum tube, whether it's audio enthusiasts tackling their first build, or more experienced amplifier designers seeking to learn the ropes of working with valves. The practical side of this book is reinforced by numerous clear illustrations throughout. **$29.99**

Electronic Gadgets for the Evil Genius

by Robert Iannini



The do-it-yourself hobbyist market — particularly in the area of electronics — is hotter than ever. This books gives the "evil genius" loads of projects to delve into — from an ultrasonic microphone to a body heat detector, all the way to a *Star Wars* Light Saber. This book makes creating these devices fun, inexpensive, and easy. **$24.95**

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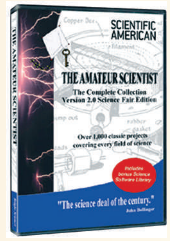
The Amateur Scientist 2.0 Science Fair Edition

from "The Amateur Scientist" column

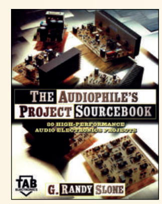


This CD contains the complete collection — 73 years — of articles from *Scientific American Magazine*'s legendary column "The Amateur Scientist," plus a second Science Software Library CD with dozens of shareware and freeware programs to feed the passion of any science nut. With over 1,100 projects to challenge science enthusiasts of all ages and skill levels — rated by cost, potential hazard, and difficulty — this is the ultimate resource for anyone interested in home-based science. If that's not enough, it also contains over 1,000 bonus pages of additional how-to science techniques that never appeared in *Scientific American*. Great for science fair students, hobbyists of all ages, and home-schoolers! In fact, *The Amateur Scientist 2.0* contains a special primer for science fair students. Fully text-searchable and packaged in an attractive double-CD case, this remarkable browser-based product runs seamlessly on every platform — Windows, Macintosh, Linux, and Unix.

$24.99 — Subscriber
$29.99 — Non-subscriber

The Audiophile's Project Sourcebook: 80 High-Performance Audio Electronics Projects

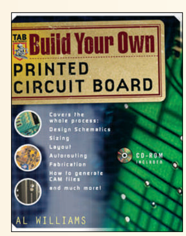
by G. Randy Slone



The Audiophile's Project Sourcebook is devoid of the hype, superstition, myths, and expensive fanaticism often associated with high-end audio systems. It provides straightforward help in building and understanding top quality audio electronic projects that are based on solid science and produce fantastic sound! **$29.95**

Build Your Own Printed Circuit Board

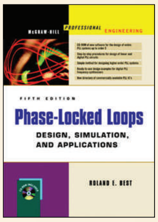
by Al Williams



With *Build Your Own Printed Circuit Board*, you can eliminate or reduce your company's reliance on outsourcing to board houses and cut costs significantly. Perfect for advanced electronics hobbyists as well, this easy-to-follow guide is the most up-to-date source on making PCBs. Complete in itself, it even gives you PCB CAD software — on CD — ready to run on either Windows or Linux. **$27.95**

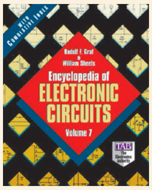
Call 1-800-783-4624 today! Or order online at www.nutsvolts.com

Phase-Locked Loops
by Roland Best



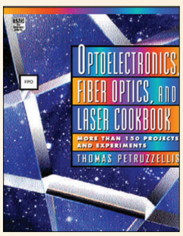
The fifth edition of this classic circuit reference comes complete with extremely valuable PLL design software written by Dr. Best. The software alone is worth many times the price of the book. The new edition also includes new chapters on frequency synthesis, CAD for PLLs, mixed-signal PLLs, and a completely new collection of sample communications applications. **$79.95**

Encyclopedia of Electronic Circuits, Volume Seven
by Rudy Graf



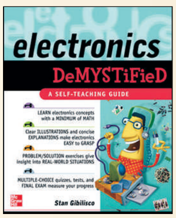
Designed for quick reference and on-the-job use, the *Encyclopedia of Electronic Circuits*, Volume Seven, puts over 1,000 state-of-the-art electronic and integrated circuit designs at your fingertips. This collection includes the latest designs from industry giants, such as Advanced Micro Devices, Motorola, Teledyne, GE, and others, as well as your favorite publications, including *Nuts & Volts*! **$39.95**

Optoelectronics, Fiber Optics, and Laser Cookbook
by Thomas Petruzzellis



This is a practical guide to one of the hottest fields in electronics and optical circuits. A collection of hands-on experiments and projects for the student, technician, and hobbyist, it explains optoelectronics in nontechnical terms. Projects show how optical circuits work and how to use them in practical and efficient ways. You'll save time, money, and energy with dozens of do-it-yourself projects — from laser alarm systems to high-speed fiberoptic data links. Circuit diagrams, schematics, and complete parts lists accompany each project and an appendix lists suppliers for needed parts. **$29.95**

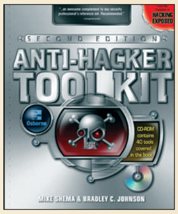
Electronics Demystified
by Stan Gibilisco



Best selling *Demystified* author and electronics expert Stan Gibilisco has penned the perfect introductory book for consumers, hobbyists, and students alike. Coverage includes essential topics, such as current and power supplies, wireless, digital principles, measurement and monitoring, transducers and sensors, location and navigation, and more. **$19.95**

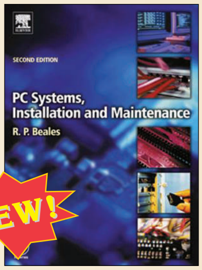
Home Computing

Anti-Hacker Tool Kit, Second Edition
by Mike Shema / Brad Johnson



Get in-depth details on the most effective security tools and learn how to use them with this hands-on resource. A must have companion to the bestselling security book *Hacking Exposed*, this tool kit includes tips and configuration advice for getting the best results from the top hacking tools created and in use today. **$59.99**

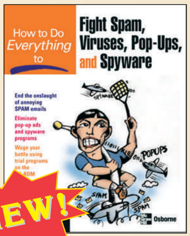
PC Systems, Installation and Maintenance, Second Edition
by R. P. Beales



NEW!

Written in a straightforward, easy-to-read style, Rob Beales provides the knowledge and techniques needed to build, troubleshoot, and maintain personal computer systems. Case studies and practical working examples are included throughout the text, with additional case studies specifically aimed to meet the requirements of e-Quals courses on an accompanying website. Further web resources include key figures from the text available to download in full-color, with a wealth of extra material covering Binary/Hex and basic logic functions, ASCII tables, connector types and pinouts, bus slots, RAM slots, and further useful website links. **$29.99**

How to Do Everything to Fight Spam, Viruses, Pop-Ups, and Spyware
by Ken Feinstein

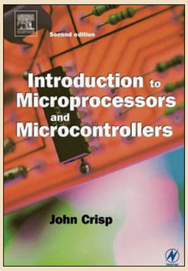


NEW!

Swat spam, vanquish viruses, knock down pop-ups, and expose spyware with help from this one-of-a-kind resource. Loaded with insightful advice, practical tips, and trial software, this book-and-CD defense will help you rid your computer of the perils and nuisances of web surfing once and for all. Author and tech expert Ken Feinstein gives easy-to-understand explanations of the technologies at work and just exactly what steps you can take to take back your Email, your surfing enjoyment, your privacy, and your computer. **$24.99**

Microcontrollers

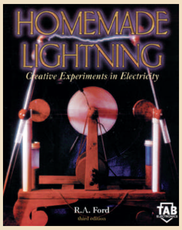
Introduction to Microprocessors and Microcontrollers
by John Crisp



Assuming only a general science education, this book introduces the workings of the microprocessor, its applications, and programming in assembler and high level languages, such as C and Java. Practical work and knowledge-check questions contribute to building a thorough understanding with a practical focus. This book concludes with a step-by-step walk through a project based on the PIC microcontroller. The concise but clearly written text makes this an ideal book for electronics and IT students and a wide range of technicians and engineers, including IT systems support staff and maintenance/service engineers. **$34.99**

High Voltage

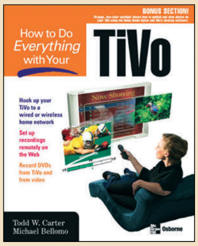
Homemade Lightning: Creative Experiments in Electricity
by R. A. Ford



Enter the wide-open frontier of high-voltage electrostatics with this fascinating, experiment-filled guide. You'll discover how to make your own equipment, how electricity is used in healing, and how experiments in high potential physics work! **$24.95**

Home Entertainment

How to Do Everything with Your TiVo
by Todd Carter



Turn on your TV! This helpful resource helps you select the best TiVo service based on your needs, then shows you how to set up your TiVo, watch live television while your it, record programs, hook TiVo up to your home network, remotely schedule programs to be recorded over the Internet, use multiple TiVos, and much more! **$24.99**

If you don't see what you need here, check out our online store at **www.nutsvolts.com** for a complete listing of the titles available.

Electronics Showcase

Reader Feedback

(Continued from Page 6)

we are using the definition of resistance and we are not using Ohm's Law. We can find various expressions for power by using the definition R=E/I. These are valid for nonlinear devices (diodes, light bulbs, varistors, etc.), as well as for linear devices. That is, the expressions do not depend on Ohm's Law. My views on Ohm's Law might be considered too picky, but still, it would make my day to come across an article for beginners that explains why Ohm's Law really is a law and not just a definition. Even though that didn't happen this time, I think the article was quite well done and useful.

Bob E. Baker
Carmichael, CA

Dear Nuts & Volts:

I read with great interest the article entitled “Smith Chart Fundamentals” in your August 2004 edition of *Nuts & Volts*. The Smith Chart is a device that I wanted to learn more about for some time and this article was a good starting point. I hope you will feature additional information about the Smith Chart in future editions.

What prompted me to write was the notation of three citations in the article that — as best as I could tell — were not printed. Citation number 1 was associated with the last sentence of the first paragraph under the subheading “The Inventor” after the words “... match the line to space.” Citation number 2 and 3 were associated with the first sentence of the first paragraph under the subheading “What Is a Smith Chart?” after the words “Although there are many computer programs ...” I appreciate if you could provide me the citations, as well as publish them for other readers.

Ed Wilk
via Internet

The references were accidentally omitted in the article, though they are printed here. — Editor Dan

References

(1) “Phillip H. Smith: A Brief Biography by Randy Rhea,” Noble Publishing.
(2) The ARRL Radio Designer also has a Smith Chart utility.
(3) Smith Chart computer program written by The Berne Institute of Engineering. A demo version can be obtained at ***http://sss-mag.com/zip/smith_v191.zip***

Dear Nuts & Volts:

I noticed two errors in the July issue. The first is in the “Let's Get Technical” article, where a “Table 1” is referenced that I can't seem to find. The second is in the “Microcontrollers Are Great” article, where it is stated that “it is sufficient to understand that a NAND gate's output only goes high when its two inputs are low,” which is incorrect. I guess the author meant to say that the output only goes LOW when the two inputs are HIGH.

Karl Arndt
via Internet

Dear Nuts & Volts:

Your readers should be aware of the potential danger in building the LED Night Light project as described by the author. Ping pong balls are made of nitrocellulose which is an extremely flammable substance. A spark on the AC input wiring due to sloppy construction of the night light could cause the ping pong ball to burst into flames rapidly and violently.

Ivan Zuckerman
via Internet

Dear Nuts & Volts:

In the article “Stamp Application, Expansion Made Easy” in the May 2004 column by Jon Williams, the author compares a new expansion chip to an older one, calling the older a “schoolyard sissy.” I bristled at the use of this derogatory term. The use of such terms in any publication — technical or otherwise — promotes prejudice and encourages violence against certain groups of human beings. I realize it was only a casual reference, but many times we just do not concieve of the damage that terms like this can cause.

Andy LaTorre
Otto, NC

Dear Nuts & Volts:

The following might add to the understanding of voltage, as an electrical analog of pressure. I think we all have an intuitive feeling for the fact that, when pumping compressed air into a tank, the added potential ENERGY is equal to the PRESSURE times each small addition of VOLUME. When pushing more electricity into a capacitor, the additional ENERGY is equal to the VOLTAGE times each small addition of CHARGE.

Dan Shanefield
via Internet

by Dr. Ralph Lorenz

Java Power

Building a Thermoelectric Mug

This Month's Projects

The Fuzzball Rating System

To find out the level of difficulty for each of these projects, turn to Fuzzball for the answers.

The scale is from 1-4, with four Fuzzballs being the more difficult or advanced projects. Just look for the Fuzzballs in the opening header.

You'll also find information included in each article on any special tools or skills you'll need to complete the project.

Let the soldering begin!

Be the envy of your colleagues with this über-nerd coffee mug that generates power from heat using the same energy converters that are used on deep space probes! Equipping a mug with thermoelectric energy converters and heatsinks will allow you to drive a small motor or other electrical device. You can even claim to be environmentally responsible by extracting useful work out of heat that would otherwise just go to waste.

Deep space probes like Cassini or Voyager are too far from the sun to use solar cells. They derive their energy instead from RTGs (Radioisotope Thermoelectric Generators), which are basically armored canisters holding plutonium dioxide fuel, which stays hot due to radioactive decay. Because these generators must work reliably for decades in space with no intervention for adjustment or lubrication, NASA needed a no-moving-parts way of generating electricity, instead of some kind of piston engine. The answer is thermoelectric converters — semiconductor junction devices that generate a current as heat flows through them. Although they are not very efficient, they are robust and reliable.

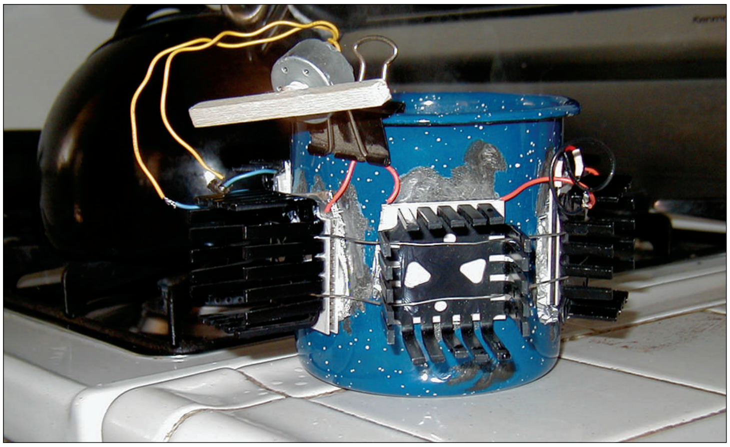
Thermoelectric devices were once rather exotic and difficult to obtain, but the performance of modern microprocessors is such that they produce enormous amounts of heat, which must be removed efficiently to prevent overheating of the chip. So, little thermoelectric plates have become widely available. Here, I will show how you can use these in reverse to generate electrical power.

Thermoelectric Devices

The thermoelectric effect is the generation of an electrical current at the junctions of two dissimilar materials (originally metals, but the effect is larger for certain semiconductors like silicon-germanium and lead telluride) if the junctions are at different temperatures. It is quite a small effect — only a few microvolts per degree Centigrade. The effect is reversible — if the temperatures of the two junctions are switched, the voltage reverses. It is also reversible in that if a current is supplied to the junctions, one will become cold and the other warm — heat is being transported by the electrical current.

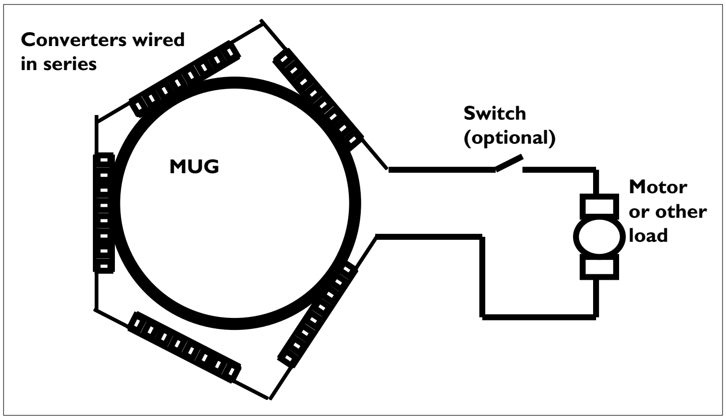
The thermoelectric cooling modules we'll use in this project are an array of around 100 pairs of p-n junctions, wired in series. They are sandwiched between two thin ceramic plates to make it easy to mount them with good thermal contact to a heatsink. This also allows the device to be cooled. Typically, these are supplied with a few amps of current at 12-15 V and they can transport several tens of watts of heat. Note that the heatsink and fan on a typical CPU installation must reject not only the heat transported from the CPU by the cooling plate, but also the additional heat produced by the plate — that 12 V, times several amps, is another

Close-up of the Thermoelectric mug. The blue enameled steel mug has been hammered flat in places. Five thermoelectric modules are strapped on with their heatsinks using bare tinned copper wire. The output of the modules is wired to a small motor with a balsa wood propeller.



several tens of watts of heat.

In this project, we'll supply heat to the converter and draw a current from it. When heat is flowing through the converter (which will have an efficiency of typically 1% if the temperature difference across it is about 30° C), negative charge appears at the heatsink side (the "cold end") of the converter in the N-type legs. Note that an effective heatsink is crucial — it is no use making the whole converter hot: one side must be hot and the other cold.



Circuit diagram. Five converters are wired in series (note polarity!). They are in thermal parallel (i.e., the same temperature difference is driving them all). Heatsinks are omitted for clarity.

Improving Performance

Thermal conduction is like electrical conduction — the flow of heat is like a current and temperature is like voltage. The thermal circuit is a chain of resistances from the high voltage (the hot liquid) to "ground" — the cool air. If the thermal resistance is low, then the "current" or heat flow will be highest.

One of the resistances in the circuit is the thermal converter itself. Ideally, this is the largest resistance in the circuit, so that most of the power is dissipated in the converter and not in useless resistances elsewhere.

So, the other resistances (thickness divided by thermal conductivity) should be minimized — this means a thin-walled mug made of a thermally-conducting material like metal. Similarly, the heatsink should be effective. The better the heatsink, the cooler it will be and, thus, the temperature difference across the converter will be maximized.

Poor contacts between surfaces can introduce very high thermal resistances — unless surfaces are ground exceptionally flat and perfectly aligned, a lot of airgaps fill the contact area with contact being made only through little bumps in the surfaces. The way to minimize these resistances and the temperature drops they cause is to use a thermal grease or heatsink compound that fills these little gaps with a relatively conductive material.

The voltage produced by the converter is proportional to the temperature across it — this is, after all, the way thermocouples are used as temperature sensors. The current produced by the converter is proportional to the heat flow through it. The heat flow through the converter is proportional to the temperature difference across it. So, the power produced by the converter (current times voltage) is, therefore, proportional to the square of the temperature difference. This is why it is vital to maximize the temperature difference by hot liquid, conductive mug and contacts, and a good heatsink.

To extract the most electrical power from the converter, it is important to choose the load impedance carefully

Resources

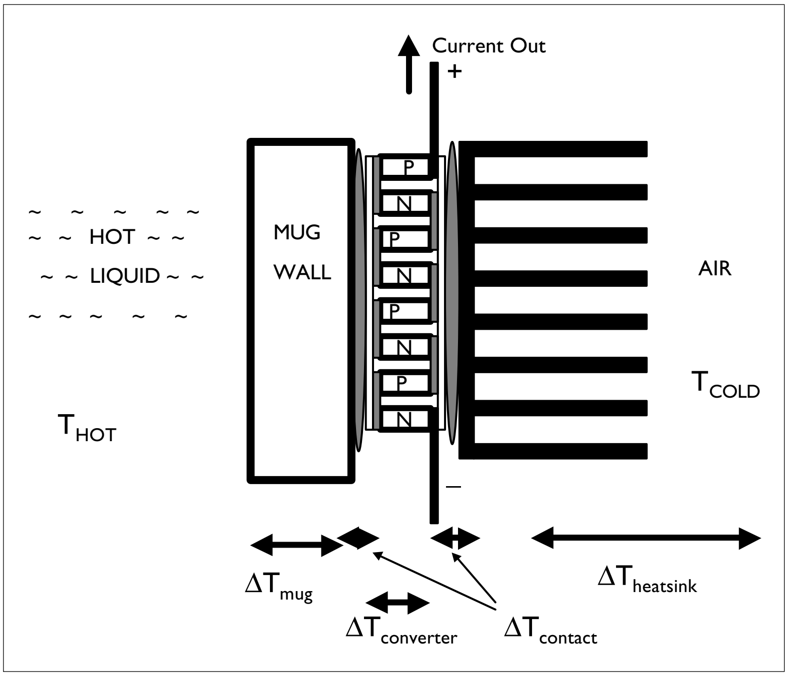
Thermoelectric Cooling Modules can now be found in many electronic parts stores and catalogs. One manufacturer/vendor is Magaland Technology, Inc. (**www.leadingtechnologysales.com**). I used several of their ICE-IT TEC 1-12705S cooling modules (40 x 40 x 3.8 mm, rated max 15.4 V at 5.2 A for cooling).

Another manufacturer is TE Technology (**www.tetech.com**) with a wide range of modules ($100.00 minimum order). I have also used their TM-TB-127-1.4-1.05(P) modules (40 x 40 x 3.8 mm, rated 15.7 V 8.6 A). TE Tech's website also has a lot of technical papers you can download.

The mug in action. The propeller spins for around 20 minutes.

(just as for a photovoltaic cell). Using a very high impedance load measures the open circuit voltage, but admits a very small current. On the other hand, a low impedance gives a high (short circuit) current, but a tiny voltage. Somewhere in between, there is an optimum impedance (usually just a few Ω) that sucks a decent current out of the converter without letting the voltage drop too far. For these kinds of converters, the short circuit current can be rather high, so you more or less want as low an impedance as possible.

There is a cascade of temperature drops from the hot liquid to the air. In order to maximize the power output, we want ΔTconverter as high as possible, so ΔTmug must be low, as well as ΔTcontact (e.g., heatsink compound, represented by the long, thin ellipses) and ΔTheatsink (large heatsink).



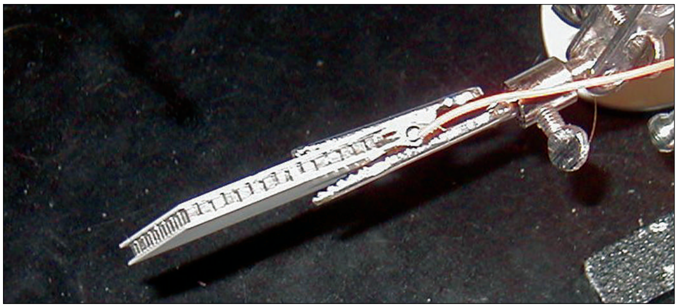
Constructing Your Mug

One difficulty is that a mug is cylindrical, whereas the converter is flat. One possibility is to find or make a square or hexagonal mug — or perhaps bash some flat surfaces onto a tin mug. Another approach is to make some adapter pieces to help mate the converter to the mug; if you're ambitious, you could machine these out of metal. My quick-and-dirty approach is to wad up aluminum foil, which acts as a fairly conductive — but moldable — material.

You could make the construction of the mug as robust as you like — using machined parts or glue. On the other hand, if — like me — you just want to try it for awhile before using the converters in another project, you could strap the converters on to the mug using some steel or bare copper wire, twisting the wire tight on the mug handle to hold everything in place.

I found that, with 40 mm heatsinks and a steel mug with flat sides, I could typically get about 0.3 volts and several tens of milliamps out of each converter. To get higher voltages, the simplest approach is to mount more than one converter (in thermal parallel, but electrical series). I used five — about as many as there was room for on a large mug — to get about 1.5 V. If someone can come up with a circuit that can multiply DC voltages of a few hundred millivolts up to several volts, it would make these converters much easier to use! Note that thermoelectric devices are like solar cells or batteries — they have a polarity, which depends not only on their internal wiring, but also the direction that heat is flowing through them. So make sure that you wire them correctly to add their voltages!

So, what can you drive with this sort of power? An LED works pretty well — 20 mA is certainly enough, but you'll need to make sure you have enough voltage from the converters to exceed the forward voltage drop of the diode. Some LEDs can have forward voltage drops of 2 V or more, but some that are as low as 1.4 V will work better. Some small DC electric motors will run on a volt or less, but you'll need to make sure it runs smoothly enough at low current. Motors sold in solar power kits may work well; one I use was ripped from an old CD player. I glued a small balsa wood propeller onto it to make it very



Close-up side view of a thermoelectric cooling module.

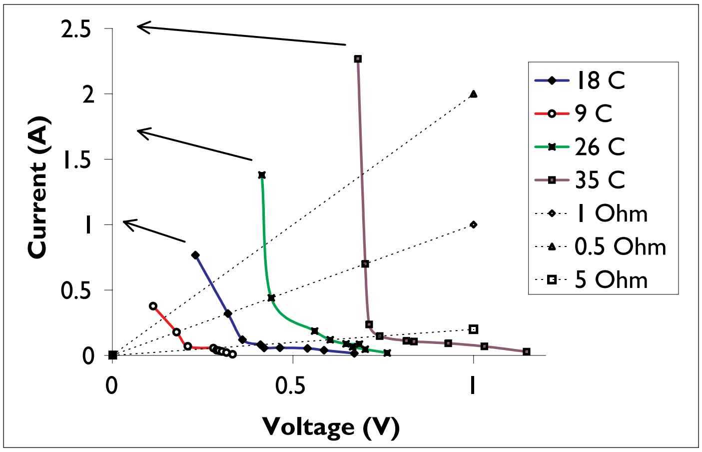
obvious when the motor was spinning. My mug, with five converters on it, ran this motor for about 24 minutes before the voltage dropped too low.

Some Closing Thoughts

Be careful! Hot liquids can cause nasty burns. Remember also that the cooling fins may be hot, so don't jab them into your face if you drink from the mug. Also, if you hammer an enameled steel mug to make flat surfaces for attaching the converters, beware of the enamel spalling (glass flakes).

Of course, if you want to explore or demonstrate the performance of thermoelectric converters, you needn't use an actual mug. You could attach the converter to a die-cast aluminum box and use that as a receptacle for hot water. A limiting performance factor in the mug is the "cold end" temperature afforded by the heatsink. You can get much higher performance from the converter if you sandwich it between two boxes: one with hot water and the other with cold water — or better yet, ice.

Don't be tempted to go too far with pushing power out of your converters. If temperatures exceed 100° C significantly, the semiconductors can degrade and the solder that bonds the junctions can melt — a eutectic bismuth/tin solder that melts at only 138° C is widely used to make thermoelectric modules!



I-V characteristic of cell. The datapoints are the voltage and current I measured with various temperature differences (9, 18, 26, and 35° C) across the converter (ΔTconverter). The higher the current drawn, the lower the voltage, although it is a very nonlinear function. Arrows show schematically how the curves must turn over to reach a "short circuit" current, though I didn't measure that. The dotted lines show schematically how different load impedances will draw power. To be efficient, a load impedance of 1 W or less is ideal.

This is a somewhat expensive project, given its rather frivolous nature. New thermoelectric modules sell for about $20.00 apiece, so there is about $100.00 of converters in the five-converter mug. You might want to experiment first with a single converter. However, as these devices become ubiquitous in CPUs, they may start appearing in surplus outlets and become available at lower prices. You might be able to salvage some from old PCs. **NV**

by Ron Newton

The Electronic Sniffer

An Electronic Nose That Knows ...

My wife and I were taking our morning constitutional walk up the hill when I noticed the smell. The wind was from the south.

"Do you smell that?"

"What?" she said, "I don't smell anything."

"Our neighbor must be gluing some PVC pipe or fiberglassing something." I didn't think much more about it, but the smell continued off and on for the next couple of weeks.

A month later, the wind was from the north and we had taken a different route.

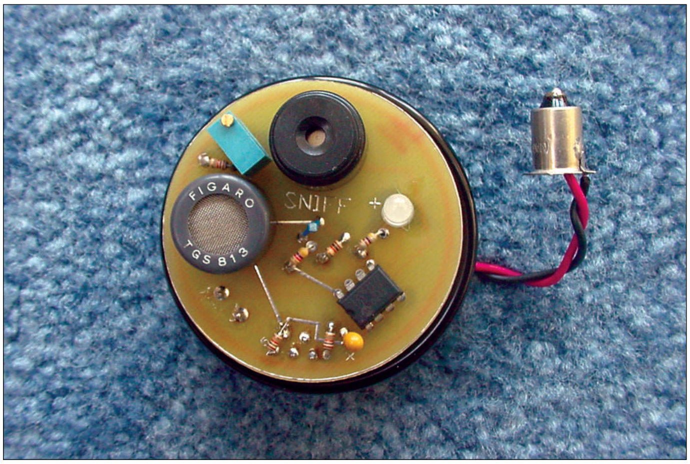
"Wow!" I said, "Is that ever strong!"

"I don't smell a thing" she replied. Then, it hit me like a ton of bricks. I am a retired chemist and I don't know why it hadn't clicked before: acetone or ether or a combination thereof. There was a drug lab in the neighborhood.

I went home and scrounged through my junk box and I found a Figaro TGS 822 gas sensor. I breadboarded it up to a 12 volt battery and hooked up a voltmeter. It still functioned. Human noses quickly become desensitized to odors. The Figaro gas sensors do not. It didn't take me long walking around the neighborhood to find the house the smell was coming from. I called drug enforcement and explained my suspicions. Three months later, there was a drug bust.

Everyone does not need one of these things to find a neighborhood drug lab, but it has many other uses. By changing the sensor, you can detect the following: propane, methane, hydrogen, carbon monoxide, ammonia, hydrogen sulfide, organic solvents, CFCs, and carbon dioxide, to name a few.

Parts placement on the PCB.



Methane is found in mines and is odorless. Miners used to carry a canary to detect it. So, if you are exploring mines, it might have a use. Carbon monoxide is also odorless and is a deadly killer and can be found in tunnels — or around your gas appliances. Ever wonder what the carbon monoxide level is in the Holland Tunnel? The carbon monoxide unit can be used for checking out bad gas heaters or has use with fire departments. The TGS 822 is good for organic solvents.

The project is simple. It uses a round board that fits into the head of a four D cell Mag-lite that is available at any hardware store. You can find them for less than $20.00 if you shop around. The good thing about using this flashlight as a power source is that there are no modifications required and you are able to still use it as a flashlight. Many of the sensors, like the TGS 822, have a heater and draw a hefty current 660 milliwatts or 132 milliamps. The D cells will power the unit for 24 hours. The TGS 822 cost is $14.50, as of the January 2004 price list. Other sensors vary in price. All are obtainable directly from Figaro.

Methodology

The heater requires a 5 volt regulated power supply. I used a low drop out National LP 3875, which will allow operation down to 5.1 volts, but doesn't exceed 7 volts input. A Wheatstone bridge is used to provide the most sensitivity and correct for the ambient temperature. As the sensor changes its resistance when it encounters a gas, the voltage changes across the Wheatstone bridge. The brain of the unit is a PIC12C671 A/D microprocessor. The voltage from the Wheatstone bridge is fed into the microprocessor and, with some simple math algorithms, is converted into sound. A bi-color LED is used to make sure you are on the right side of the crossover point of the Wheatstone bridge.

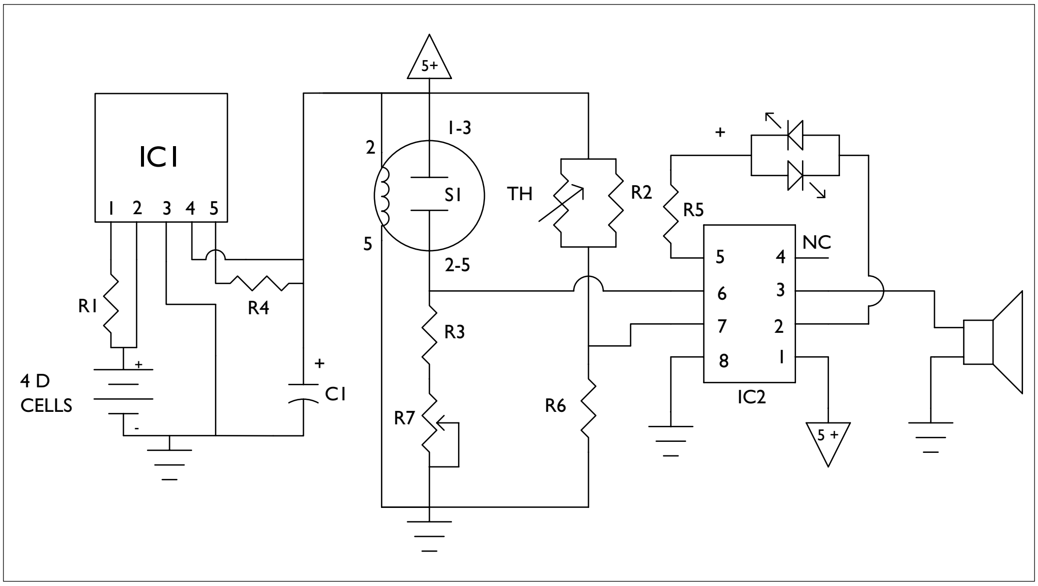
Construction

You will need a programmer to program the PIC chip or it is available pre-programmed (see Parts List). The code is listed on the *Nuts & Volts* website: **www.nutsvolts.com**

All of the components — with the exceptions of the

terminal and the voltage regulator — are soldered to the top of the board with the word "Sniff." The sensor's six pins are designed to be mounted, regardless of its position; however, the sound transducer is marked with polarity. The long pin of the LED goes to the pad marked +. There are four holes for the different pin spacings of different sound transducers.

The voltage regulator is soldered to the bottom side of the board, along with the two-pin terminal. Pin 1 is marked for the voltage regulator. Take some red fingernail polish and mark the terminal next to the R (red wire) for ease of wire connection.



The schematic showing the regulator, sensor, Wheatstone bridge, PIC processor, and output indicators.

To make the bulb adapter, use an extra PR4 bulb and break the glass. Clean out its base and solder a red wire to the center and a black wire to inside the case. The wires should be about 1.5 inches long. Tin about 1/4 inch of the ends. This adapter allows the unit to be connected to the

How the Sensor Works

Most of the Figaro sensors use micro-grains of sintered tin oxide (SnO_2) that have been heated to a high temperature. This causes oxygen to be absorbed on the grains and provides a positive potential in the space charge between the molecules. When a reducing gas — such as acetone, alcohol, propane, etc. — is passed over the sensor, the sensor's resistance drops. The resistance is linear logarithmically over ranges of a few parts per million (PPM) to several 1,000 PPM. For those not familiar with log scales, what it amounts to is that a large change in PPM will cause a small change in resistance, e.g., 100 PPM may give a resistance of 2,000 Ω, but a 1,000 PPM would give a resistance of 1,000 Ω. For those who want the formulations, here they are:

$$Rs = A[C]^{-\alpha}$$

where: Rs = electrical resistance of the sensor
A = constant
[C] = gas concentration
α = slope of Rs curve

It is normal for the sensor to have a large drop in resistance when it is first turned on. Once the heater warms up, the unit will function normally. The sensors will respond in a matter of seconds.

Humidity and temperature will also affect the sensor's resistance, whereas humidity is difficult to correct for (but not impossible). I considered it a minor problem due to the nature of the project. Temperature is compensated for by the thermistor in the circuit.

Although the sensors are pretty rugged, avoid silicon vapors and corrosive vapors, such as H_2S, Cl_2, HCl, and SO. Don't get the sensor wet and, if it does get wet, don't allow it to freeze or it will crack the sensing material.

Prices vary with the sensors. Here is a short list:

The following models sell for $14.50 and detect these gases:

TGS813	LP-gas/propane
TGS822	Alcohol, toluene, xylene, acetone, etc.
TGS842	Natural gas/methane
TGS24420*	Carbon monoxide
TGS2600*	Air contaminants
TGS2610*	General combustible gas

* Require different mounting configurations

These models sell for $23.25 and detect:

TGS830	CFC R-22 and R-113
TGS831	CFC R-22 and R-21
TGS832	CFC R-22 and R-134a

Finally, these models sell for $56.30 and detect:

TGS821	Hydrogen
TGS825	Hydrogen sulfide
TGS826	Ammonia

Figaro also makes oxygen sensors, but they are rather bulky and will not fit on the flashlight. Visit them at **www.figarosensor.com** for spec sheets and order info.

The assembled sensor board installed in the Mag-lite body.

flashlight without having to split the knurled nut that holds the bulb.

Using the Unit

Remove the lens, reflector, and the bulb from the flashlight. Place the bulb adapter into the bulb holder and screw on the knurled nut. Connect the wires to the board, minding the polarity. Put the board into the lens holder and screw it onto the flashlight. Prevent the board from turning by holding the components.

Turn on the flashlight. The LED should light either red or green. The sound transducer may be squeaking. Let the unit warm up for about two minutes. Adjust the potentiometer until the LED turns green. As the unit stabilizes, the pot may need adjusting.

Open a bottle of rubbing alcohol and place the unit near the top of the bottle. Any bottle of alcohol will work just as well. The LED should turn red and the speaker should change tone. The higher the tone, the more parts per million of vapor are present. When you place the unit in clean air, the tone should fall and the LED should switch back to green.

The unit can also be used to check someone's breath to see if they have been drinking. Just have them blow toward the sensor from about two feet. The unit is, however, qualitative and not quantitative. It does not mean the person is drunk. Do you need to check to see if a drink has alcohol in it? Just place the unit over the glass. Try it with a glass of wine.

Check out **www.figarosensor.com** for more specifications on using gas sensors and their detection limits.

Happy sniffing! **NV**

About the Author

Ron Newton is a retired clinical scientist with degrees in chemistry and electronic engineering. He volunteers his time to the Republic of Georgia Pediatric Hospitals (Asia) by providing consulting and teaching in the fields of blood banking and bacteriology, and provides instruction in the repair of hospital equipment. He also donates his time to NASA by providing R&D in the field of photonics and hopes to have his spectrometer design for the determination of ultraviolet light spectrums on one of the upcoming Mars shots.

Circle #75 on the Reader Service Card.

by Gerard Fonte

Mr. E. Machine: The Enigma Machine — Part 4

De-bunking Kirlian Pseudo-science

This is the last part of the Enigma series. In some ways, it should really be the first because The Enigma Machine grew out of these high power observations. It was only after the electrical, physical, and chemical experiments were performed that enough information became available to design it.

In this article, we won't use The Enigma Machine. Instead, we'll look at its big brother and see what it can do. We'll see how Kirlian pseudo-science is just a flawed and fanciful misinterpretation of actual science. We'll also discuss ELF (Extremely Low Frequency) effects (usually from power lines) that have been linked to health problems. Finally, we'll look at some current research that could have significant practical applications.

Figure 1. Conventional sparks are made with the switch connected to ground. Non-current-carrying sparks are un-grounded and pass to large, lead mass.

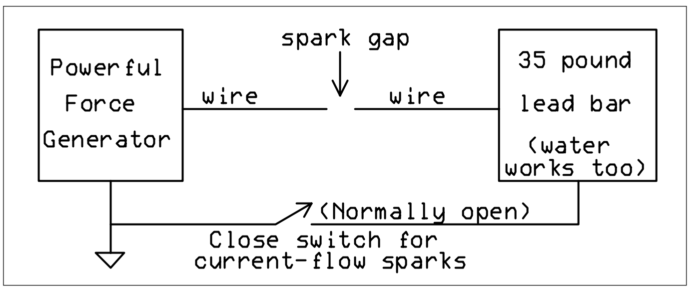
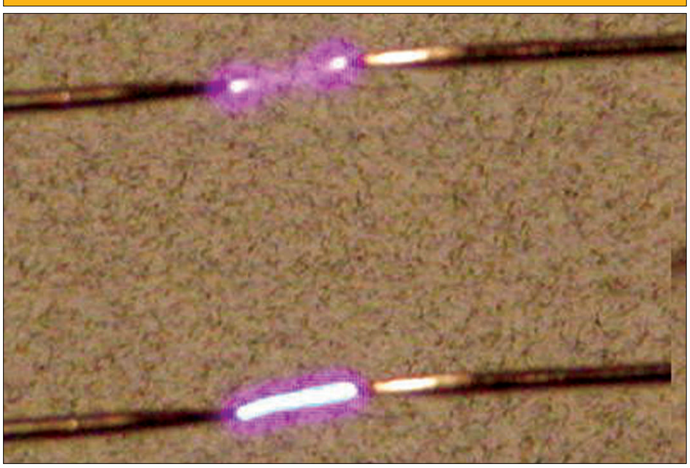


Figure 2. This is a composite photograph that shows the difference between a non-current-carrying spark (top) and a conventional current-carrying spark (bottom). There is a significant difference in sound, as well.



Nomenclature and Apparatus

Since the effects are created without the movement of electrons, there is no electrical current flowing (see previous articles). It's not really electricity in the commonly used sense of the word; therefore, I will use the word "force" to refer to this transfer of an electrical charge without an electrical current.

I'm not going to describe the high power apparatus in detail. This is done to prevent unqualified and inexperienced people from getting hurt. The high power apparatus does have the potential to give very painful shocks and burns. (I know from experience.) An experienced and qualified person should be able to recreate the apparatus from my general descriptions and the previous articles. I will be happy to provide details to academic institutions or other research interests upon request.

Anatomy of a Spark

An electrical spark of the same length, using the same electrodes, must be the same, right? That's what I thought. However, that's wrong. Figure 1 shows the basic setup, which creates about 3/16 inch sparks. Figure 2 is a composite photograph showing the difference between a common current carrying electrical spark to ground and a force spark under identical conditions. You can easily see that they are very different.

The photographs do not show exactly what the eye sees. In real life, the force spark has a lighter blue color and looks continuous (no break in the middle). There is also a very significant audible difference. The common electrical spark is very loud. The force spark can be nearly inaudible. Both sparks can be drawn to the same length (> 1/4 inch). The force spark has no current flow (no deflection with a 50 µA meter). The electrical spark has significant current flow (slams the meter full scale).

At one time, I found that a very substantial amount of force was passing through my body without any sensation. The amount was sufficient to draw sparks (about the same length as in Figure 2) from the tips of

insulated wire-cutters I was holding to a metal plate. This is very different from high frequency or RF skin effects. The operating frequency was nowhere near high enough to create RF skin effects. I know this because I have inadvertently allowed current to flow in several occasions, giving me a very painful shock. As we saw last month, the charge-transfer mechanism is different.

How can there be a spark without current, though? Isn't a spark electricity? Actually, it is not. When you see a spark, you are seeing ionized air (mostly nitrogen and oxygen). It typically has a blue hue, depending on the intensity of the charge. (Lightning looks white because there is so much current that the air is significantly heated.)

Electron transfer in a vacuum is invisible. If you've ever looked at an operating vacuum tube, you know that there is nothing to see other than the glow of the filament. Sparks occur whenever there is enough energy to ionize the atoms in the air.

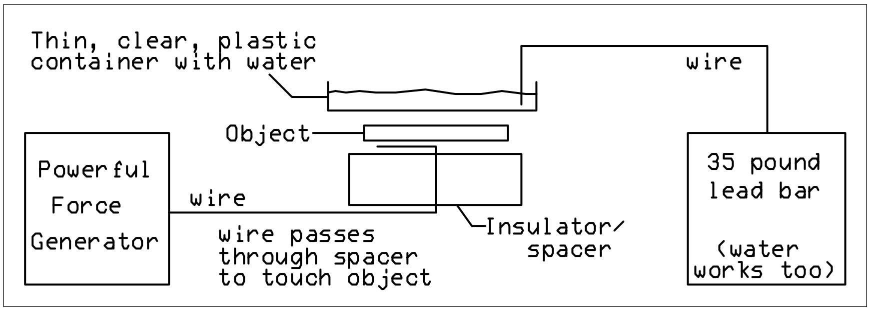


Figure 3. The basic setup for corona discharge photography. Refer to Figure 4 to see the physical layout.

Corona Discharge

A more general ionization — called a corona discharge — also occurs for the same reason. However, a corona discharge is not a simple point-to-point ionization. It occurs over many points or even a whole area. Visually, it can be quite striking. Figure 3 shows the basic setup for performing the corona discharge experiments. Figure 4 is what the experiment looks like in normal light. If you look closely, you can see the force wire enter from the left. The tip of an alligator clip, which goes to the lead bar, is barely seen at the top. Figure 5 is what the corona discharge of the silver dollar looks like in a darkened room. Since it's hard to photograph without light, a 16 second time exposure was used. This blurs the discharge somewhat. The eye sees tiny tendrils of glowing blue that dance about.

You don't have to use metal to create the corona discharge. Anything that is either an electrical or force "conductor" will work. I used an ordinary leaf for Figure 6. Initially, I was going to scrap that photograph because of the burn-through in the middle of the leaf (that bright white area in the middle) that washes out the corona. However, I realized that this also shows something important. There is enough electrical charge to burn and char organic tissue. In other words, polar conductivity (see previous articles) has the capability to transfer real and significant power without any measurable electrical current or its associated magnetic field.

I should probably mention that I have unintentionally found myself holding a well-insulated wire with a corona discharge that traveled into my hand. There was no sensation of electrical shock. It felt more like touching spider webs. On one occasion when this happened, I squeezed the wire between my thumb and forefinger and the wire felt warm. I don't think the actual wire temperature had increased, since the wires were never warm when the power was off. I think my skin was heating up, just like the leaf.

Another aspect of corona discharge is that material from the charged object can actually be removed and re-deposited. Figure 7 shows the plastic container after a few minutes of corona discharge with the silver dollar. You can see that the deposits exactly match the corona discharge that is illustrated in Figure 5. Most of this residue (which is, presumably, silver) is easily wiped off, but some seems to be embedded into the plastic.

Kirlian Photography

Kirlian Photography is quite different from the pictures presented here. Their setup places photographic paper or film in close contact with the object, as shown in Figure 8. If the metal plate is large enough, no additional "conductive mass" may be needed. Sometimes, they use a system ground that has the potential to allow real current to flow. For large objects (like a person's finger), they place the photographic film (with or without the glass) on top of the metal plate and have the person touch that. The person

Figure 4. The corona discharge photographs are taken through a water filled, thin, plastic container. The power goes in from the left, up through a hole in the wood, and touches the bottom of the coin. The tip of the alligator clip is just visible at the top center. It connects the water to a lead mass.

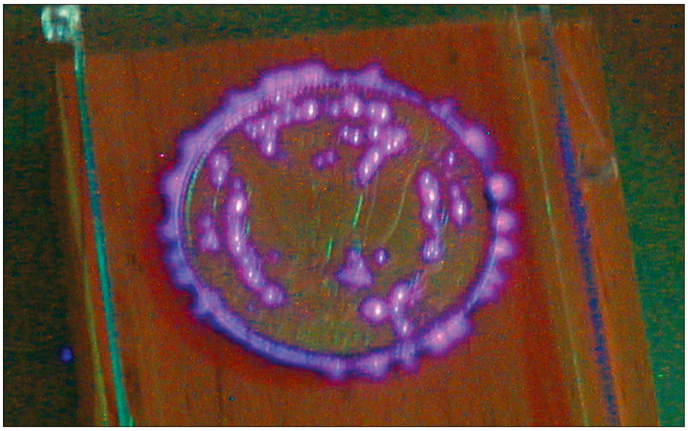


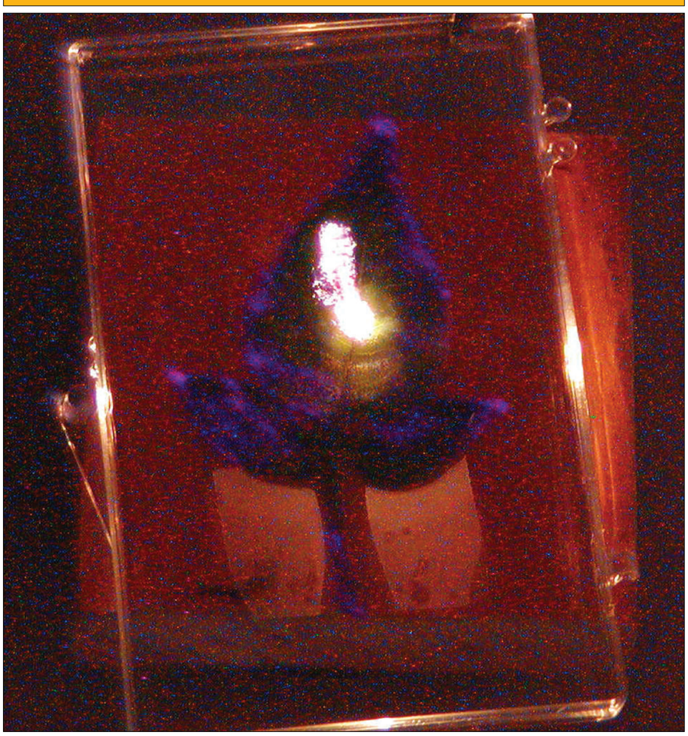
Figure 5. This is a time exposure of a corona discharge.

then acts as the conductive mass. Note that, with standard Kirlian photography, the corona is not actually seen, only its effects on the film are recorded.

Kirlian followers believe that they are witnessing some special "life aura" in these photographs. (They have many colors and are certainly interesting and pretty.) It is their belief that this aura is metaphysical or paranormal and has little relation to actual physical conditions. Since they believe rather than understand, no amount of logic and reason can cause them to consider any alternative explanation. (If it's an aura of life, why do ordinary metal objects also show an aura?)

However, to an objective observer, the aspects of the Kirlian "force" are quite clear. Their apparatus generates a large electrical charge. The charge orients the molecules in the target — be it a leaf, a human being, or a house key — and creates a corona discharge. The "aura" they see is air ionization, also known as St. Elmo's Fire. The peculiar measurement effects are due to polar conduction rather than conventional electrical conduction. There is nothing paranormal about it.

Figure 6. The corona discharge of the leaf is washed out by burn-through. There is plenty of power to char the leaf, even though no current is measured.



If the target is in contact with photographic paper, impressive colors are observed, but this is explained by the fact that photographic emulsions are also sensitive to electrical charge. The colors are simply the result of the emulsions reacting electro-chemically. That is why the same colors are not seen in non-contact photography.

The "phantom leaf" experiment is easily explained. This is where an intact leaf is photographed first. Then, part of the leaf is cut away and another photograph is taken. Sometimes, the outline of the whole leaf is seen in the second photograph. The Kirlian interpretation, as I understand it, is that the leaf still feels that it is whole, so the aura is complete. (This is somewhat similar to the real "phantom limb" effect, where human amputees feel a limb that is no longer there. However, this effect occurs because humans have a complex central nervous system. Plants do not have a central nervous system.)

Here's what I see happening. During the first photograph of an intact leaf, Kirlian photographers typically press the leaf under the glass. This pressure can be up to several pounds or more. This physical contact with the glass — along with the electrical ionization — deposits moisture and/or small amounts of plant material. When part of the leaf is removed, this material remains. (Take another look at Figure 7 to verify this.)

The high conductivity of water conducts the molecular orientation force even though it may be invisible. (Note, engineers working with high voltage apparatus know the problems of invisible films of moisture or other contamination. I have personally witnessed sparks skipping several feet over an old, wooden desk to an outlet ground with my apparatus.) I confidently predict that, if the Kirlian apparatus is thoroughly cleaned after every photograph, no "phantom leaf" effects will be seen. I also predict that, if the only photograph is of the leaf after it has been cut, no phantom effects will be seen, either.

The "kissing" effect is also easily explained as a moisture film effect. In this experiment, two volunteers each place one finger in very close proximity to the other's finger. However, the fingers are far enough apart that no Kirlian "force" is seen passing between the fingers. Then, the volunteers kiss passionately. As they do, the "force" is seen between their fingers (as a small spark).

It can, however, be seen that there is nothing mysterious here. It is well known that there are many physiological changes that occur during sexual stimulation. Some of the very obvious changes are the generation of sweat, the increase in body temperature,

and the increase in blood pressure. The result is that a person's hands get moist. This film of moisture conducts better than dry skin. Thus, while dry fingers are far enough apart to prevent air ionization, the moist fingers are not.

We've seen that skin is an insulator. The moisture breaks down the insulation of the skin. Thus, sparks are seen. It is confidently predicted that anything that causes similar physiological effects will show the similar Kirlian effects — or will simply show that wet fingers "spark" closer than dry fingers.

I do not claim to know all there is about Kirlian effects. However, I do know that whatever I have found can be simply explained with polar conductivity, corona discharge, and/or the poor execution of experiments. There is nothing mysterious or magical about this force, regardless of what some people would have you believe.

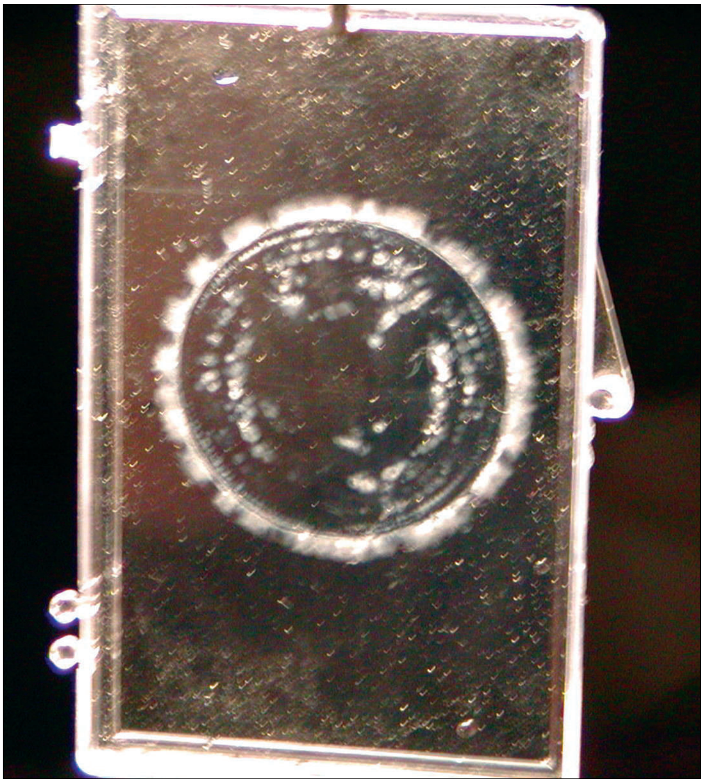


Figure 7. This residue is from the corona discharge of the coin. Some could be wiped away, but some was permanent.

ELFs

Recently, there has been a great deal of interest in determining if Extremely Low Frequency (ELF) RF radiation has harmful effects. These studies have looked at high voltage power lines, police radar, cell phones, and other fairly common sources of low power and/or low frequency radiation. (Note, radar and cell phones are included, even though their operating frequency is not "extremely low.")

In general, the answer (so far) seems to be that there is no connection between these sources and human health. However, the methods of measurement are generally conventional electric current or RF power techniques. It has been shown that these methods can be misleading when measuring this force. It suggests that testing for molecular rotation might be useful.

Additionally, the seed germination experiment discussed in last month's article is very suggestive. It seems quite reasonable to expect subtle cellular effects when large, complex polar molecules are rotated by an external force. Many organic molecules' shapes and orientations are critical to their function. It also appears reasonable to expect that molecular rotation at different frequencies would have different effects, depending on the natural resonant frequency. It seems to me that the seed germination experiment should be replicated independently. This could be important.

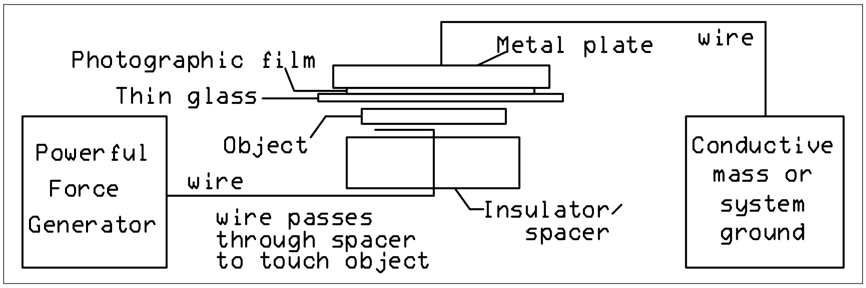
Other Research

In the mid 1960s, unconventional scientist/experimenter Wallace L. Minto crested a flurry of interest in "Plasmonics" or "Hydronics," which was described as a new form of wireless communication (*Popular Electronics*, March 1966, Volume 24, No. 3, pages 50-53). There are many similarities between the research and demonstrations he performed and the effects described here over the last few months. These similarities were only recognized after I had done the bulk of my research years ago. Additionally, Minto's devices were black boxes and he kept everything secret about the process. So, it cannot be known for certain what his equipment consisted of.

Minto's work was mostly concerned with communication. "Voice transmission via Plasmonics through the single wire was unaffected when the wire was cut and capacitors, resistors (extremely high values), chokes, or even diodes back to back were inserted and the 'circuit' completed" (reference above). We saw a similar effect with the battery/ground effect last month, where a large resistance to ground made a significant difference in performance.

You can reproduce his results by physically grounding a battery lead through various components and values while The Enigma Machine runs on batteries. Back-to-back

Figure 8. Typical Kirlian photography goes directly to photographic film or paper; the photographers don't actually "see" what they're photographing. That makes it seem much more mysterious.



diodes (small signal type) and a straight wire connection show no significant difference.

There is one demonstration that Minto performed that I have not yet been able to directly replicate. He showed that the conductivity of a 5% sucrose solution varied significantly with frequency; peaks and valleys showed on a chart recorder. I've tried this several times without success. However, since Minto's equipment was secret, it's impossible to determine if he was seeing a real phenomenon or if it was just a bad experiment.

The Future of Polar Conductivity

Polar conductivity seems to be an area where very little research is being done. This means that there is a potential for novel discoveries and applications. Expensive or sophisticated equipment is not needed to explore these effects at this time. Therefore, enterprising experimenters and hobbyists could — quite possibly — make significant contributions and breakthroughs. Let's look at some areas of application.

Proximity Chemical Analysis. This is an area that I am currently researching whenever I get the time (which isn't all that often). Take a test tube of some solution and place it between a force emitter and sensor. Measure the conductivity with metal attachments to the outside of the test tube. Different solutions have different conductivities.

Currently, I can easily discriminate between saturated solutions of table salt, sucrose (cane/table sugar), dextrose (glucose/blood sugar), plain water, and cooking oil. It's important to note that the test tubes are closed and that these measurements are made without touching the liquids. In theory, this means that it could be possible to measure someone's blood sugar level or blood alcohol content (and perhaps other things) simply by placing the person's hand on an electronic device.

Underwater or Underground Communication. The Navy communicates with submarines with a huge, land-based, low frequency transmitter. It doesn't penetrate very deeply into the water, so the submarines must be fairly shallow to receive it. Since the transmission facilities are so big, the submarines can't directly respond. They have to surface and transmit with more conventional equipment. Minto demonstrated point-to-point, wireless communication from dockside to a scuba diver in the water. It seems reasonable to suggest that polar conductivity through the ground is also possible.

Medical Applications. The seed germination experiment (last month) seems to be quite notable. It was a well-controlled experiment in an academic setting. It sug-

gests that living things can be directly affected by polar conductivity. Admittedly, this is just speculation; however, consider an electronic medical device that could be tuned to prevent specific pathogens from replicating. Obviously, such a product would have a tremendous impact at many levels.

Full Circle

This series started, "This is one of those things that seems just a little interesting at the start; however, as you look closer, it gets stranger and stranger." There does not seem to be an end to the strangeness. Like the battery bunny, it just keeps going and going and going.

This series was developed to illustrate a number of aspects of science and learning. The first and most obvious was the actual development of The Enigma Machine from concept to product. Next was the scientific approach to gathering information and learning from it. Common sense and attention to detail are absolutely necessary. There was also the convoluted path of discovery from the first odd observation of hearing a sound when my ear brushed an electromagnet to the present.

Learning from mistakes is still learning. Hopefully, you found this series interesting and fun. That's what science and engineering is to me. **NV**

Enigma Machine Safety Notice!

Please use common sense ...

1. This article deals with high voltage and high voltage effects. When built and used as described, The Enigma Machine is felt to be completely safe. Improper use and construction can cause electrical shock.

2. Several Enigma Machine experiments demonstrate effects that pass through the body of the user. Therefore, it is not recommended that anyone with a pacemaker or other embedded electrical device participate in these experiments, nor should it be used in very close proximity to any electrical equipment where electromagnetic interference could cause safety concerns.

3. Several experiments have shown subtle biological effects on plants with continuous exposure of days to weeks. (See last month's article.)

4. The high power version of the Enigma Machine presented here should not be built or operated by anyone who is not experienced with high voltage circuits. Severe electrical shocks or burns are very possible.

5. It seems reasonable to suggest that the high power version could have significant biological effects, especially with long term exposure.

by Michael Simpson

Floating Light Show

Mix Colors and Software for a Neat Effect!

After opening the pool this year, I decided to purchase some sort of lighting system so we could enjoy those muggy Virginia nights. I wanted a color system that lit the water inside the pool. Many existing lighting systems had 12 V lights that used a transformer to lower the voltage from 110 V, but I did not want to chance something going wrong with one of these. Plus, the fiber optic systems were much too expensive, so I decided to break down and build something.

My requirements were simple:

- It must be powered by four rechargeable AA batteries. This will give a nominal 4.8 volts, which eliminates the need for a voltage regulator.
- It must last at least six hours on a single charge. Longer would be a plus.
- It must have three colors and cycle slowly between them to change the mood of the pool.
- It must be self-contained and float on the surface of the pool, yet it has to shine light on the pool floor.
- It must fit in a small, waterproof tub.
- It must be easy to build and inexpensive, so that I can build more than one. I will probably build four for my pool.

The AA batteries and six hour duration pretty much dictated some sort of LED light system. For the multiple colors, I decided to use blue, red, and green ultra bright LEDs. I wanted to use 5 V LEDs that pulled less than 25 ma so I could power them directly from the microcontroller's IO port. For more brightness, I would use two LEDs for each color, each on its own port.

For the microcontroller, I decided on an AthenaHS for its speed, cost, and simplicity. I needed to generate six PWM signals for mixing the colors. The AthenaHS can source or sink 25 ma on each port. This is perfect for the LEDs that I have chosen.

The AthenaHS also has a very small carrier board that will allow me to build the light very easily.

Circuit Hookup

Figure 1 shows the hookup to the carrier board. We only need six ports on the AthenaHS to drive the six LEDs. I decided to use a 2 x 6 female header, so I could just plug the LEDs in place. While this is not the most rugged connection method, it would allow me to experiment with different colored LEDs.

Figure 2 shows the slightly modified carrier board. You can also use two 1 x 6 female headers glued or stuck together with double-sided foam tape. Connect the free ends of the header together and tie to Vss, as shown in Figure 3.

The carrier comes with some snap connect male headers and you will only need two of them — one each connected to the + and – leads, as shown in Figure 2. This

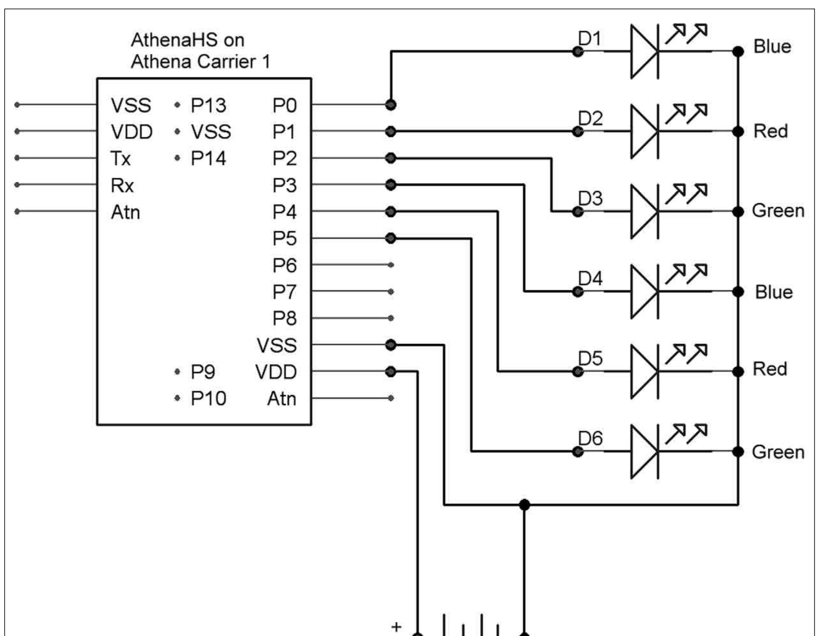


Figure 1

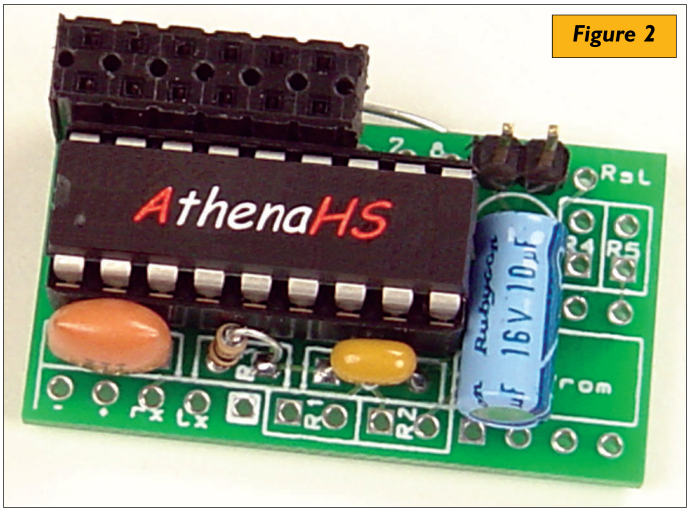


Figure 2

male header will be used to connect the batteries and female header. Other than the headers, the carrier board is built step by step, according to the instructions. When using the AthenaHS with the carrier board, you will need a 20 MHz resonator.

Once the LEDs have been inserted, you can slightly bend them into groups, as shown in Figure 4. The short LED lead connects to the outside header (vss). If you are worried about the leads touching, you can use some 1/16 heat shrink for insulation. You only need to insulate the IO port side of the LED.

Use double-sided foam tape to attach the circuit board to the battery holder. The LEDs should be centered on the battery holder, as shown in Figure 5. To turn on the light, slip the battery header over the two pin header on the board. The negative side of the battery is connected to the header pin closest to the LEDs.

The Program

The program must generate six PWM signals on ports

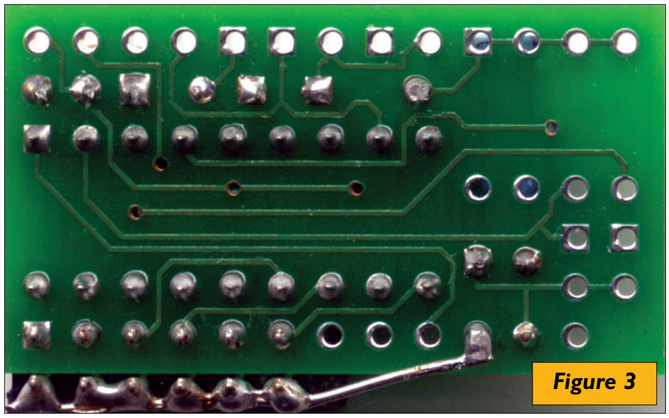


Figure 3

0-5. Three counter variables — named bluecount, redcount, and greencount — set the duty cycle of the corresponding colors.

The color pattern is set in the main loop. We start with red and green turned on and proceed as follows:

Fade out red.
Fade in blue.
Fade out green.
Fade in red.
Fade out blue.
Fade in green.

Start over.

This pattern assures that all the LED color combos are met. It also means no more than four LEDs are on at once, which will go a long way in reducing power consumption.

The actual call to the PWM routine is what lights the LEDs. At the start of this routine, we retrieve a random number to set the number of times we will actually cycle through the PWM counts. The more times we cycle, the longer it will take a particular color to fade in or out.

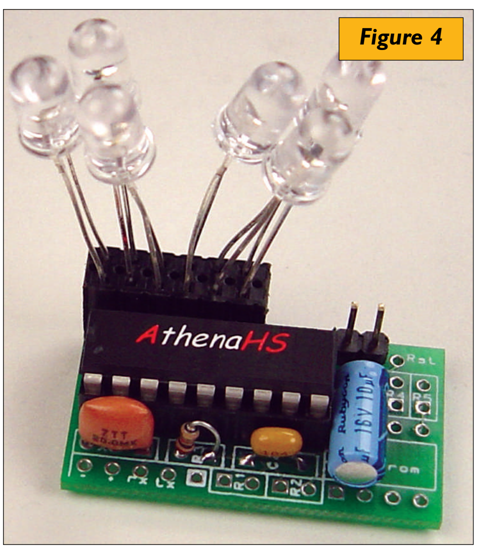


Figure 4

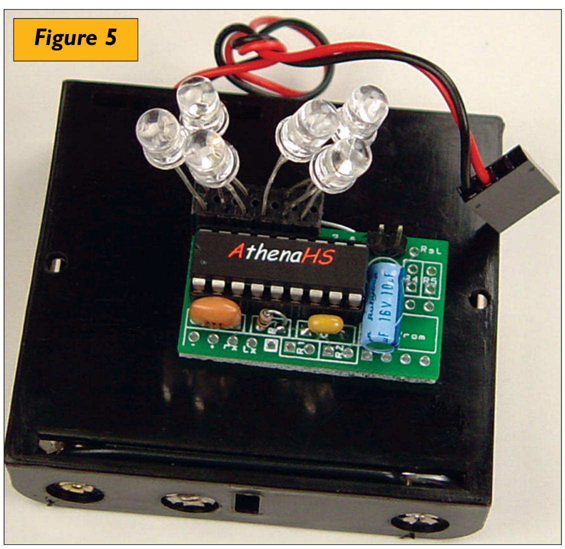


Figure 5

```
AthenaHS

 dim bluecount,
 redcount,greencount
 dim curcount,cycle,rnd

 'LED Ports
 const portblue1 0
 const portred1 1
 const portgreen1 2
 const portblue2 3
 const portred2 4
 const portgreen2 5

 const maxcount 150
'Sets up the PWM fre-
quency and resolution

 setio 0,1,2,3,4,5

 'Start Point for lights
```

```
bluecount = 1
 redcount = 150
 greencount = 150


loop:
  gosub Red_Down
  gosub Blue_Up
  gosub Green_Down
  gosub Red_Up
  gosub Blue_Down
  gosub Green_Up

  goto loop


'_________________
Blue_Up:
'_________________
 for bluecount = 1 to maxcount
  gosub pwm
 next
 return

'_________________
Blue_Down:
'_________________
 for bluecount = maxcount to 1 step -1
  gosub pwm
 next
 return

'_________________
Red_Up:
'_________________
 for redcount = 1 to maxcount
  gosub pwm
 next
 return

'_________________
Red_Down:
'_________________
 for redcount = maxcount to 1 step -1
  gosub pwm
 next
 return

'_________________
Green_Up:
'_________________
 for greencount = 1 to maxcount
  gosub pwm
 next
 return

'_________________
Green_Down:
'_________________
for greencount = maxcount to 1 step -1
  gosub pwm
```

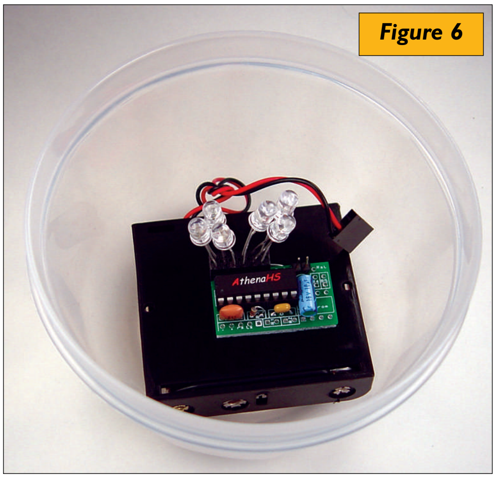


Figure 6


Figure 7

Tub Construction

The actual tub construction is very simple. Using a Rubbermaid #5193 tub, simply set the battery and circuit board assembly into the tub with the LEDs facing up, as shown in Figure 6. This is a one pint container and the battery holder centers pretty well without much effort. If you use a different size tub or battery layout, you will have to make sure the assembly is centered so that the tub does not tilt to one side.

In order for the lights to illuminate the pool bottom, you need to reflect the LEDs downward. I have used several reflectors, such as compact mirrors or convex mirrors. Out of all the tests, aluminum foil seems to work the best at reflecting the light because all the little crinkles tend to mix the colors more evenly. You can use double-sided foam or tape to attach the foil to the inside of the lid. Make sure the shiny side is down, as shown in Figure 7.

That is pretty much it for the tub construction. You can add some flowers or a rubber ducky to the top of the tub, if you wish.

```
'_____________________
' Generate the light
'_____________________
pwm:

 random 40,rnd   'This will determine how long
                 'we stay with a color
 rnd = rnd + 5   'With a minimum of five counts

 'To create the six PWM signals we turn all ports on
 'then turn them off as each color count is reached.
 for cycle = 1 to rnd
 configio 0,1,2,3,4,5
  for curcount = 1 to maxcount
   if curcount = bluecount then
    gosub offblue
   endif
   if curcount = redcount then
    gosub offred
   endif
   if curcount = greencount then
    gosub offgreen
   endif
  next
 next
 return

 'You may want to place this code directly in the if
 'statements. The KRcompression technology built into
 'the Athena engine is centered around modular code so
 'this particular way is more efficient than single if
 ' statements

'Port Handlers
offblue:
  input portblue2
  input portblue1
  return
offred:
  input portred1
  input portred2
  return
offgreen:
  input portgreen1
  input portgreen2
  return
```

How Well Does It Work?

My wife loves them and can't wait for the long, hot days of summer. My hard-to-impress daughter wants the five units I made to be used at her next pool party.

I'm getting over 12 hours of use out of the lights, so my next step is to add a small solar cell to charge the batteries during the day.

Be sure to visit Kronos Robotics at **www.kronos robotics.com** for project updates, as well as more light patterns. **NV**

Sources

AthenaHS	Kronos Robotics #16277
Athena carrier 1	Kronos Robotics #16300
20 MHz resonator	Kronos Robotics #16140
Four cell battery holder	Kronos Robotics #16323
Snapable 1 x 36 female header	Kronos Robotics #16291
Plastic Tub	Rubbermaid # 5193
Ultra bright LEDs	
Blue LED	All Electronics #LED-74
Red LED	All Electronics #LED-94
Green LED	All Electronics #LED-57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BOOK REVIEW

The Digital Consumer Technology Handbook

by Ed Driscoll, Jr.

A Stellar Book ... but With Many Minor Flaws

On April 3, 2000, when President Clinton's Justice Department issued its ruling that Microsoft had violated US antitrust laws and the NASDAQ plummeted 349 points (or 7.64%) — its worst single-day performance ever — it signaled the end of the Internet bubble. The next year, the horrific terrorist attacks on the US occurred on September 11th. As a result, we've seen much less of what Tom Wolfe once dubbed the "digibabble and fairy dust" that ruled the 1990s and, somehow, technology has slipped a bit below America's collective radar screen.

Yet, in many ways, the rapid speed of technological progress hasn't abated. In the late 1970s, we saw the birth of the personal computer, the VCR, and the laser disc. In the 1980s, compact discs, cell phones, and fax machines entered the picture. Today, average consumers are surrounded by more technological goodies than we know what to do with and keeping pace with what's available and their benefits can be a daunting task.

The Digital Consumer Technology Handbook is a new book (published by Newnes, go to **www.xilinx.com/esp/dct_handbook.htm**) written by Amit Dhir, a manager in the strategic solutions marketing group at Xilinx — a 20-year-old, San Jose-based semiconductor manufacturer. Dhir has a Bachelor of Science in Electronic Engineering from Purdue University and a master's degree in the same field from San Jose State University.

At 656 pages, *The Handbook* would make a heck of a doorstop or paperweight, but it does a pretty nifty job as an encyclopedic look at just about every major technology that competes for your money, time, and living space.

Not Bad — but Not Perfect

It's not perfect, however, and its minor flaws only serve to highlight how — with a little more work — this book could have been flawless.

Occasionally, Dhir gets a bit too cute. On page one of the book, he refers to "Generation D — The Digital Decade." Well, is it a decade or a generation? Since a generation is about twice as long as a decade, I'd say those are mutually exclusive terms. Shortly thereafter, Dhir writes, "Anything that is digital is superior." I'm as far from a Luddite as can be imagined, but I'm not sure if I'd want to make a blanket statement like that. There are far too many professional photographers who love their 35 mm and 4 x 6 format negatives and professional recording engineers who love the warmth of 2" wide analog tape who might seriously blanche at having to switch to digital.

From time to time, Dhir throws in a buzz word and assumes that the vast majority of his readers will know what it means. He mentions Moore's Law and explains what it is and then mentions Metcalf's Law without any explanation. At times, Dhir's book makes the reader feel like it would be handy to have Google running in the background while reading it. (About half of the folks reading this just rolled their eyes and said, "Geez, is that Driscoll a dummy or what?")

Much later in the book, Dhir's otherwise excellent chapter on video games is marred by an unexplained phrase noting that Microsoft's Xbox appeals most to "game artists and aficionado players." Say what?

Chapter 4 does a thorough job of explaining how CDs work, but, at one point, Dhir writes that CDs are facing extinction. Well, the sun is facing extinction, too — give it four, maybe five billion years, tops. Between commercial recordings being released on CDs, computer programs on CD-ROM, and people using CD-Rs for both, I'd say that compact discs have a *few* more years left in them before

extinction occurs.

What *could* hasten the speed of the CD's demise are its successor formats — DVD-A and SACD (short for Super Audio Compact Disc). It appears that Dhir could have done a more thorough job of explaining how the growth of these formats has been retarded by interference by the RIAA (Recording Industry Association of America), which fears consumers copying their discs. (Which is why these CD replacement formats need their own proprietary receivers with individual digital inputs for each of the six audio channels, rather than the single Toslink or coax input that the original video DVDs and audio CDs use. Also, this is why the RIAA has made the Dolby Digital receiver you bought five years ago obsolete.)

In Chapter 7 of *The Digital Consumer Technology Handbook*, Dhir has a through explanation of the benefits of DVD and how the format was created. Then he mentions Divx — the Circuit City-backed early attempt at creating a rental DVD format that was *loathed* by the early adopters who first put DVD on the map. Dhir writes that the format "played a useful role," but fails to note the backlash it caused and the confusion it created by introducing a Beta/VHS format war so early in the DVD's lifespan.

Later in the DVD chapter, he writes, "The number of [DVD] titles will be limited in the early years." Early years? The format is seven years old! Limited? According to the official DVD Faqs (available online at **www.thedigitalbits.com/officialfaq.html** among other locations), by the end of 2002, there were about 23,000 DVD titles available in the US — and that number has only grown since. That doesn't sound too limited to me.

A Few Missing Technologies

Aficionados are bound to see one or two technologies they would have liked to have seen mentioned. While PCs and spin-off technologies are well represented, I personally would have liked to have seen some information on weblogs. Their inherent ease of use and flexibility are causing them exponential growth in popularity, since they allow for instant self-publishing on any topic imaginable.

Seemingly a Must-Have

All of this may sound like nitpicking and, in a way, it is; as I said, Dhir has written a terrific book that seems to be a must-have title for anyone with an interest in consumer electronics, where most of us have expertise in one area, but have blind spots when it comes to knowledge of other technological niches. Hopefully, *The Digital Consumer Technology Handbook* will inform its readers — and allow them to make informed decisions when it comes to spending their hard-earned money on electronics. It reads like it could have used another round of editing before it was released, though. A book like this will need fairly frequent revisions if its sales are successful, so let's hope things get tightened up the next time around. **NV**

New Life for LORAN

Part 2

by Clifford Appel

Last month, I explained how LORAN (LOng RAnge Navigation) worked as a navigational aid system and how it was originally implemented using vacuum tube transmitters. This month, we will continue with the story of the retirement of the world's most powerful vacuum tube LORAN transmitter of 1.6 megawatts at the US Coast Guard station at George, WA. The vacuum tube transmitter went on air in September of 1976 and was officially taken off air on December 8, 2003. After switching the antenna transmission line from the vacuum tube transmitter, a new solid-state transmitter was operating within about two hours. Read on to learn about the new solid-state concept and LORAN's future.

The Solid-State Transmitter

The differences between the vacuum tube transmitter(s) and the new solid-state transmitter are like night and day. This should be the case because of a 25 year period to improve transmitting efficiency and frequency/control techniques from computer technology.

The transmitter known as the Accufix 7500 is manufactured by Megapulse of North Billerica, MA. Megapulse has supplied earlier versions of the Accufix, known as the AN/FPN-64, which were of lesser output power capability for USCG LORAN stations, primarily in the inland areas of the US. Megapulse has recently finished supplying units to the nation of Japan for their LORAN chains.

The new frequency/control equipment is shown in Figure 1. At the left are two Transmitter Control Subsystems (TCS) — one active and one standby. The TCS controls precise timing of the transmitted LORAN pulses and also monitors the "quality" of those pulses.

Third from the left is the Transmit Frequency Equipment (TFE), which generates George, WA's LORAN rates of 9,940 and 5,990 as the old equipment in Figure 2 of last month's article did for the vacuum tube transmitter. To the right of the TFE is the AUX rack containing three Hewlett Packard HP-5071A Cesium Beam Frequency Standards. Each Cesium costs over $28,000.00 and they are the reason the LORAN signal is so repeatable with time to its users. In a one day period, HP rates the frequency stability as better than 3×10^{-14}. You don't get that kind of stability from a TCXO (Temperature Compensated Crystal Oscillator), which is a common option in our HF amateur radio equipment.

Figure 1. The frequency/control equipment for the solid-state transmitter. The two left racks are the TCS, then there is the TFE, the AUX rack with three cesium beam frequency standards, and two RAIL racks on the right. Love that alphabet soup! Photo courtesy ETC K. Anderson.

Two racks on the far right (only a portion of one is shown) are the RAIL (Remote Automated Integrated LORAN) equipment, similar to what was used for the vacuum tube transmitter. The RAIL — consisting of commercial grade Dell computers — provides timing corrections, system alarms, a means to input "commands" to the TFE and TCS, and also acts as a communications tool to the control monitors. For the Canadian West Coast Chain (5,990 rate) the control monitor is

located in St. Anthony, Newfoundland. For the US West Coast Chain (9,940 rate), the control monitor is located in Petaluma, CA. The control monitor insures the proper timing and synchronization of all the LORAN stations in the chain.

The TCS rack mentioned earlier controls the pulses in the new solid-state transmitter, shown in Figure 2. You will also notice there are vertical panels consisting of four sections. Each section is called an HCG (Half Cycle Generator). Two sections work in parallel to form the positive half of the LORAN pulse and the other two sections form the negative half of the pulse. The HCG consists of beefy inductors, hefty capacitors, large diodes, and large SCRs (Silicon Controlled Rectifiers), which “bang” a tuning coil to “build” the LORAN pulse. In a way, this transmitter can be thought of as a sophisticated, electronically controlled, spark-gap transmitter. This is a totally different concept than what was used in the vacuum tube transmitter that can be described as a super large class B linear amplifier.

The HCGs are fired in groups at various time intervals to resonate and amplify the 100 kHz pulse. This is no simple task because the whole output network must take into account the LORAN antenna. Once the peak of the pulse is reached, some means must be made to dampen the trailing edge of the LORAN pulse. That dampening of resonance is accomplished by a network with the distinguished title of “tailbiter.” The TCS has a lot of responsibility for HCG firing, tailbiter operation, and output network tuning. The output network is constantly being massaged as the antenna sways (changing impedance) or environmental conditions change (rain, snow, icing, low humidity, dust storms).

The Accufix 7500 transmitter produces 1.3 megawatts — a bit less than the AN/FPN-45 vacuum tube transmitter’s 1.6 megawatts — but the solid-state unit has some virtues that the vacuum tube rig lacks. If an HCG should fail, the Accufix will still put out a signal, albeit at a slightly reduced output power. An HCG can be swapped out while the transmitter is operational. Corrective maintenance for the Accufix is simpler, less time consuming, and a lot cheaper than what was required for the vacuum tube transmitters. There is only the one solid-state transmitter running 24/7, as opposed to the two vacuum tube rigs which were alternated every two weeks.

If you remember, earlier I mentioned that the vacuum tube transmitters could require an electrical “demand” of nearly 1,000 kilowatts and that I calculated that each transmitter required 100 kilowatts just to light the filaments. The entire building that contains the new transmitter, frequency/control equipment, heating/cooling equipment, and lighting uses about 170 kilowatts. That’s a dramatic reduction of electrical energy consumption by nearly six times. Utility bills will go from about $9,000.00 per month for the vacuum tube LORAN equipment to about $2,200.00 per month for the solid-state LORAN equipment.

LORAN Antennas

There are three basic types of LORAN antennas used at the US Coast Guard stations (see Reference 3). Two are common monopoles (towers) — either 625 feet tall or 700 feet with top loading elements (i.e., “capacitance hats”) to decrease capacitance to ground. Under each type of monopole is a counterpoise of radials buried in the earth. The monopole sits on a stout glass insulator which isolates the tower from ground. At the LORAN frequency of 100 kHz, we can calculate that one wavelength is 3,000 meters. Therefore, the 625 and 700 foot towers are about

Figure 2. The new Accufix 7500 solid-state transmitter. The right side is a mirror image of the left side, prominent in the picture. Photo courtesy of ETC K. Anderson.

Figure 3

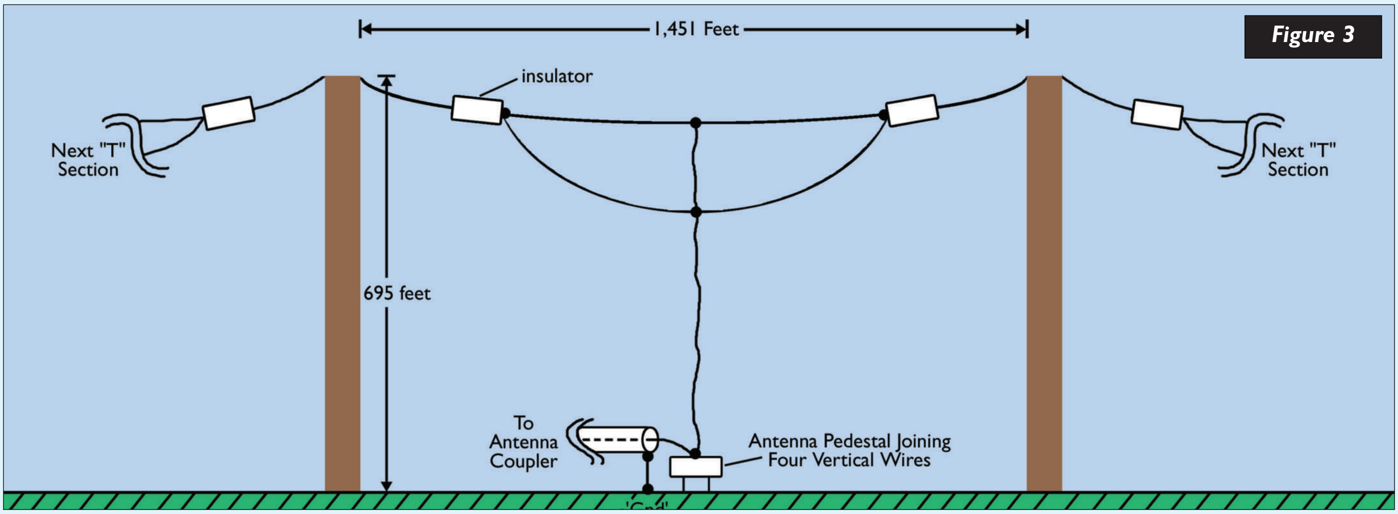


Figure 4. Backup generators for the vacuum tube transmitter. Each unit is rated at 400 kW. Photo courtesy of ET1 K. McKinley.

7% of a wavelength. As a result, the impedances of the 625 and 700 foot tall antennas are 2.5-j25 Ω and 4.0-j23 Ω, respectively. Not much there, huh? You can bet that great effort is made to produce a good counterpoise to reduce ground loss as much as possible.

The third type of LORAN antenna — the one used at George — is the SLT. I've seen "SLT" defined several ways, but the drawings at LORAN Station George call it a "Sectionalized LORAN Transmitting" antenna. There are four other LORAN stations using an SLT, so it's not unique to George. The SLT is a wire antenna consisting of four "T" sections slung between four towers. Each tower is 695 feet tall and arranged in a perfect square — 1,451 feet on a side. One "T" section held up by two towers is shown in Figure 3. The horizontal sections are suspended and insulated from the towers; the towers do not radiate electromagnetic waves. None of the "T" sections are connected to another. The bottom of the vertical wire is connected to the bottom of the other three vertical wires from their respective "T." If you use your imagination, you can think of the SLT as a conical monopole with the upper half sliced off or you can think of it as a "fat" monopole.

I will relate to you this "sea story" regarding the SLT, although I have yet to find the source of the story. More than 30 years ago, when the Coast Guard was modeling SLT antennas, the computer predicted an impedance of "about" 5.5 "real" Ω. Compared to a 700 foot monopole resistance of 4.0 Ω, that's a big increase and, hence, more power radiated (in theory, assuming loss resistance is a fixed value). However, when the SLT was erected and impedances were measured on the actual antenna, it was found to be 3.3-j15 Ω, a true disappointment. My guess is, though, that the bandwidth of the SLT is much broader than that of a monopole. If nothing more, the sight of flashing aircraft warning lights makes an impressive display from 25 miles away, as seen while driving on Interstate 90 at night!

Backup Power

I mentioned earlier that the vacuum tube station could use as much as 1,000 kilowatts at one time and that the new solid-state station uses about 170 kilowatts. What happens when the lights go out? The Coast Guard doesn't want that LORAN signal off air for very long. Despite the very good service and reliability of the local utility (Grant County Public Utility District), power interruptions do occur.

References

1 — **www.navcen.uscg.gov/loran** — then click on "LORAN-C User Handbook." Although this publication contains information regarding LORAN stations long since shut down, it is a good tutorial for providing insight as to how LORAN works.

2 — Private correspondence 5 March, 2004, with Bill Roland, a retired engineer from Megapulse, Inc.

3 — **www.navcen.uscg.gov/pubs/rnavbull/rnbull38.pdf** — then go to page 13 for details.

4 — **www.loran.org/Newsletters/NewsletterIndex.htm** — then click on September 2003. **www.loran.org** is the homepage of the ILA (International LORAN Association) previously known as the Wild Goose Association.

5 — **www.loran.org/Newsletters/April,2003.pdf** — page 3, "US Coast Guard reports interference to GPS from TV antennas;" an incident involving certain powered (active) UHF/VHF marine television antennas creating interference to GPS receiver operation.

6 — **http://webhome.idirect.com/~jproc/hyperbolic/loran_c_future.html** — "Excellent though GPS may be, its problem is that it is so low powered that the signal can easily be blanked out or disrupted — as demonstrated at a 1997 Moscow air show, where a jammer destroyed the signal over a radius of 200 km." The website — maintained by Jerry Proc — is loaded with all sorts of information regarding LORAN and its history, as well as information regarding other forms of radio navigation.

7 — A nautical mile is approximately 6,076 feet or about 1.151 statute mile. It is defined as one minute of longitude at the Equator — 1,852 meters.

8 — **www.megapulse.com/how%20used.html** — A concise article with diagrams explaining the extension of LORAN use.

The vacuum tube station has three 400 KW diesel generators, which will immediately start up, parallel themselves, and operate an automatic transfer switch (ATS) to provide station power when utility power is lost. Despite the fact that under emergency operation some of the station's load is shed ("non-essential" circuits), it still takes at least two of those generators in parallel to put George back on air. A view of the three generators is shown in Figure 4. The generators can be up to speed and supplying three phase 460 V AC in less than 30 seconds. The transmitter can then put itself back on air about 30 seconds after that, so the total lost signal time lost is about one minute.

Figure 5. The crew at LORSTA George who helped put the new equipment on air and shut down the legacy vacuum tube transmitters. Standing left to right: ET1 Ken McKinley, ETC Kevin Anderson, ET3 Ross McDermott, MK1 Richard Boxleitner, SK1 Sterling Van Horn. Kneeling: FN Ryan McDermott (no relation). Photo courtesy of ETC K. Anderson.

By contrast, the solid-state station has two physically smaller diesel generators, rated at 400 kW each. When loss of utility is sensed, they both start up, but only one picks up the load. They do not parallel. After five minutes, the "loafing" generator shuts itself down. All load is carried; there are no non-essential circuits, but the major difference is that the LORAN signal does not go off air at any point because there is a 240 KW UPS (Uninterruptible Power Supply) that continues electrical power to the solid-state transmitter. There's also an 8 KW UPS that supplies power to the timing and frequency control equipment shown in Figure 3 of last month's article. The UPS equipment really doesn't power the station for long because the generator can pick up the load in about 10 seconds. Wow!

The combinations of reliable, solid-state transmitting equipment, computerized control equipment, and the UPS equipment will result in LORAN signal continuity of from 99.85% to a target of 99.99% (see Reference 4). The vacuum tube equipment was achieving signal continuity of 99.70%, on average. The Coast Guard prides itself on keeping that signal on air and in tolerance for its users as much as possible.

The Future of LORAN

Where do we go from here? After spending approximately $100 million — so far — upgrading the vacuum tube stations to solid-state transmitters, will anyone use the signal? Yes, but probably not in the way LORAN was originally intended to be used.

Without question, the dominant form of electronic navigation around the world is GPS. The units are so small, inexpensive, and packed with features that a lot of amateurs have them married to a TNC (Terminal Node Controller) and two meter FM rig for APRS (Automatic Position Reporting System).

GPS is not infallible, though. Since the system was built for military purposes, the owner can move satellites around in orbit to meet whatever need there might be. This would leave other areas on the globe with "holes" of coverage. The GPS signal operates at L band and, therefore, doesn't penetrate buildings or heavy foliage very well. Its signal is so weak that it can be jammed (unintentionally) by something as simple as a poorly maintained active marine TV antenna (see Reference 5). It can also be jammed (intentionally) by a simple, low wattage, portable transmitter in the hands of the wrong people (see Reference 6).

The LORAN signal can be used as a backup to GPS because of its robust signal-to-noise capability and its low frequency of operation. It does not, however, have the pinpoint accuracy of GPS — which can be as good as 10 meters and as poor as 100 meters. The US Coast Guard lists LORAN's accuracy as 0.25 nautical mile (NM) nominally with 0.1 NM at the best of times (see Reference 7). The signal's coverage can be from 600 NM to 1,000 NM, depending upon the time of day and path.

LORAN's strong suit is that the position displayed is

repeatable every time the user returns to that same position. In other words, even though the Lat/Lon displayed on the receiver readout may not be precise, a user can return to that exact geographical position each time that those Lat/Lon numbers are duplicated.

The Coast Guard is attempting to create an extremely accurate clock among LORAN stations known as Time of Emission (TOE) control; the Coast Guard prefers its own jargon, using Time of Transmission (TOT) process. A simple explanation of how it works is given in Reference 8. This will enable a position fix using only two stations, stations in multiple chains, or even two GPS satellites and one LORAN station.

The LORAN signal can be used for more than navigation. Because of the stable cesium beam oscillators used at every LORAN station, the LORAN signal can provide precise timing for commercial users. Wireless telephone services, the radio and television industry, satellite communications companies, and the banking industry can use LORAN to keep TDM (Time Domain Multiplex) format signals synchronized. The electric utilities can use LORAN as a clock to "time tag" all their events and circuit breaker operations. A precise coordinated time tag will assist in determining the order of occurrence of happenings, such as the northeast US blackout in August of 2003.

LORAN C Station George went on air September 29, 1976. The original station complement was 10 people. With computer technology beefed up in the late '80s, the crew was reduced to seven. The new, solid-state transmitter will require a crew of only four. The savings in people costs, maintenance costs, and electricity costs will eventually pay for the up-front expenditure. The George crew that helped make it all happen is in Figure 5. As a Coast Guard Reservist, I'm honored to have worked with these professionals at this premier LORAN station. **NV**

About the Author

Clifford J. Appel, K7SPS, wrote this article for three reasons: First, he wanted to inform people that there is more to navigation than just GPS. Second, it is his salute to the Coasties, past and present, assigned to LORSTA George who've kept the equipment in top operational form since 1976. Third, he wrote it as a tribute to a deceased friend; Stan Pickarski was his working mate when he was stationed at the Coast Guard District 14 office in Honolulu, HI, from 1974 to 1976. Stan helped erect the LORAN A and C stations in the Pacific region and helped shut down the A stations decades later. He died in February, 1999, at age 78. He is missed for his friendship and his wonderful sea stories. You can contact Cliff at P.O. Box 241, Electric City, WA 99123, or by Email at cjappel@juno.com

Ham Radio FOR DUMMIES

BOOK REVIEW

by Karl Lunt

Long before the Internet, dedicated hobbyists developed their own world wide web of amateur radio stations. Often using gear they had built themselves, these radio amateurs — or hams — visited, exchanged information, passed along vital communications, and helped out in countless emergencies. Hams have contributed to fields of research as diverse as antenna theory, sunspot activity, atmospheric conditions, rocketry, and satellite communications.

Starting out in ham radio can be fun, but — as with any high tech hobby — there are plenty of hurdles to overcome. Ward Silver's new book, *Ham Radio for Dummies*, published by Wiley, offers a well-written and friendly guide to starting and growing your new hobby of amateur radio.

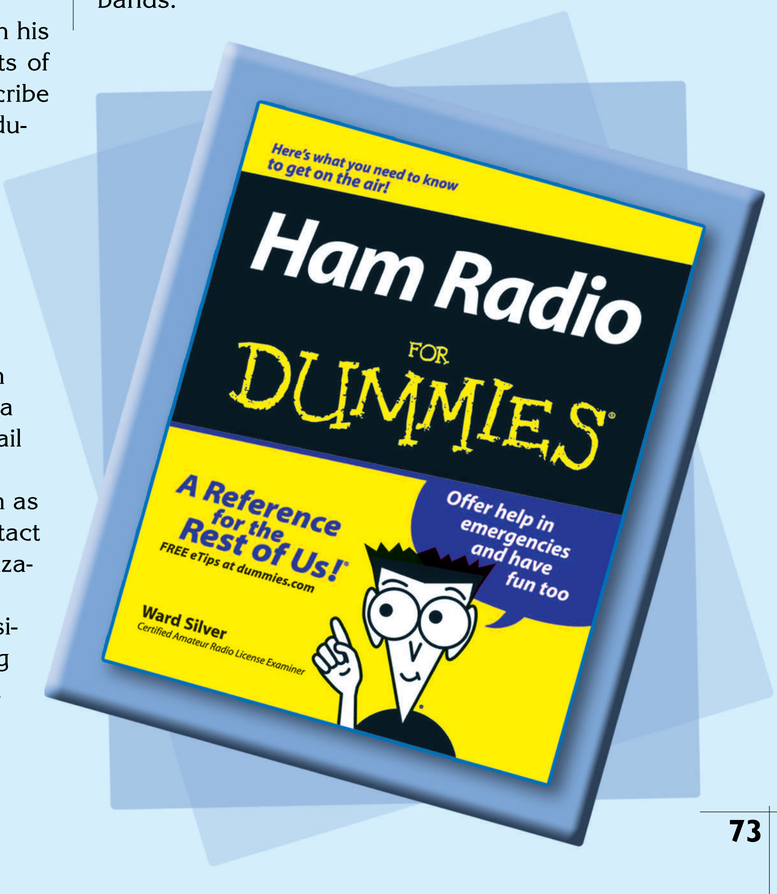
Ward, known by his ham call sign N0AX, draws on his decades-long ham career to explain the many aspects of ham radio, demystify the licensing process, and describe how to build and operate your own ham shack. His education as an electronics engineer provides the base for the technical material in the book. He is also a contributing editor and columnist for *QST* — a popular monthly ham radio magazine — and his writing skills go a long way in making this book easy to read.

The first section of the book introduces you to the ham radio hobby. The material here provides an overview of the hobby, not the fine details. You get a general description of a ham shack; much more detail appears in later sections.

Similarly, Ward devotes a few pages to topics such as radio fundamentals, basic gadgetry, how to make contact with others over ham radio, ham contests, and organizations dedicated to ham radio.

The second section gets down to the serious business of preparing for your ham radio exam. Operating a ham radio station requires an amateur radio license, which must be earned by passing an examination by the Federal Communications Commission (FCC). There are several levels of licenses available, with increasing privileges granted to those passing the more difficult tests. Ward spells out the different requirements and privileges of the Technician, General, and Amateur Extra Class Licenses. He follows this with excellent material on preparing for the exam and what to expect on exam day.

Once you earn your ham radio license, you are ready to move to the third section of the book, where Ward delves into the culture and vocabulary particular to ham radio. Bagging a QSO (making a radio contact) requires several skills — including patience and knowledge of how the different radio bands behave. Distant QSOs can really test your technical abilities and Ward provides pages of tips for working the different ham bands.



BOOK REVIEW — *Ham Radio* for DUMMIES

Though it is easy to think of amateur radio as a geek hobby, it has a large social element to it and Ward spends part of this third section on ham etiquette, clubs and organizations, and common courtesy.

He also uses this section to cover the more serious side of amateur radio. Hams play a major role in emergency response following disasters and knowing how to handle such situations can literally mean life or death to others.

Other specialties of ham radio — including DX (long distance contacts), contests, QRP (low power operation), video transmission, and awards — get good treatment here.

The fourth section is where you get your hands dirty, so to speak. Setting up your station can be a lot of fun and Ward describes some of the more important elements to consider in your shack layout.

Here, you also find much of the technical information needed to get out a strong signal and to pull in a weak one. This section also includes good tips on used versus new equipment, safety considerations, and troubleshooting problems that keep your station from running at top efficiency. Ward also provides considerable information on antenna theory and construction — a vital element of a well-built shack.

The fifth section of the book contains a set of tips and guidelines — arranged in groups of 10 — for getting the most from your new hobby. This is followed by the book's appendices, including a glossary of terms, a collection of technical references, and a fairly extensive index.

I enjoyed reading this book for its technical content and for Ward's light and concise style. As mentioned previously, he is an accomplished writer, which goes a long way to making this admittedly technical hobby easy to understand. He covers a huge range of material in the book's 350+ pages. Open the book at random and you could hit a discussion of contacting ham radio satellites, accessing amateur radio repeaters, or finding resources for studying for your ham ticket (license). The paragraphs are short and all "meat." The book's page layout is easy to follow.

This book is an excellent starting point for your ham radio hobby. Ward takes much of the mystery out of amateur radio and helps you understand its fun and challenges. His enthusiasm for amateur radio is apparent, as is his conviction that ham radio plays an important role when called upon during emergencies. With this book, Ward Silver may well become an Elmer (mentor) to a new generation of hams. **NV**

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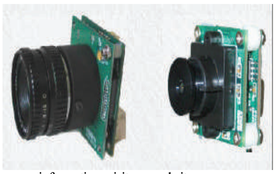
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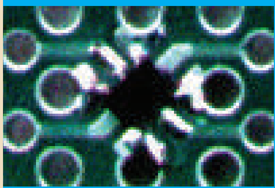

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Understanding, Designing, and Constructing Robots and Robotic Systems

Personal Robotics

A Walk on the Wild Side!

Some of us build robots for the educational aspects, others for a creative outlet. Some of us undoubtedly have a god complex or parenthood issues, but there is one thing that you can't deny and that is that robots are great for impressing your friends.

Unfortunately, after your third or fourth rolling robot (you know the ones — two hacked R/C servos and a caster or a skid), you start to crave more — more motors, more wires, more everything. You know what I am talking about; you have been there or will be, eventually. You want a walker. Not just *any* walker — you want a hexapod.

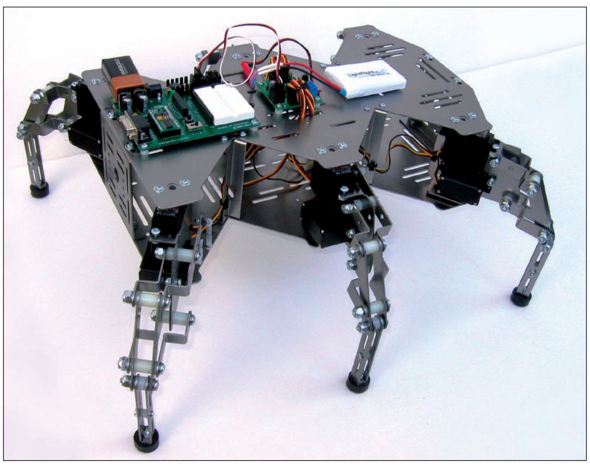
Hexapods are amazing to watch as they do their magical cockroach dance. They roam around on your workbench or living room floor, with tons of behavioral aspects to explore and myriad motions to perfect. Just getting the code running for all those servos is a challenge, let alone the intelligence behind them.

Hexapod walking has a lot to it. Even the simplest 2 x 6 presents a major technological leap over your old, two-motored carpet crawler. Efficiency, construction, geometry, and torque all take on another dimension of complexity as you size out motors for the job. Just the geometry of the joints can have a huge impact on the overall performance.

While some of us are brave enough to attempt designing and building our own walkers, others of us turn to the commercial market to satisfy our need for walking wonders. Predominant in the walker market is LynxMotion. They have been in the robot biz for as long as I can remember and it had always been a dream of mine to own one of their creations.

Apparently, they have inspired more than just admirers. CrustCrawler is relatively new to the market, but offers a slightly "higher end" mechanism than LynxMotion, if that is possible. CrustCrawler has also partnered up with the industry standard — Parallax — to provide a distributor and a complete solution.

The HexCrawler with a BASIC Stamp II brain.



The HexCrawler

Since CrustCrawler's offering — the HexCrawler — is a 2 x 6 with just 12 servos, I chose to begin my review with it.

To begin, when I opened the box, I was stunned. You have to understand that I have worked in the movie and advertising industries, where everything must be picture perfect: not a speck, not a hair out of place, no blemishes, creases, folds, or tears. Anything less than perfect is unacceptable.

It takes a lot to impress me, but Parallax's presentation of the HexCrawler did more than that; they floored me. They could have presented some nice, reeking *hakarl* (fermented shark) fresh from the sand pits and drying sheds of Iceland and I would have gladly downed it. The presentation was beyond good; it was stellar.

All the parts were in nice, labeled zip-lock bags. The glossy, spiral bound instructions beckoned to me and the shiny, anodized aluminum pieces — carefully shaped and bent — called to me. Then bags of spacers, hardware, and wire ties greeted me next — dazzling, taunting, and inviting me.

The next salvo on the senses was the bags of electronics, servo controller, processor, and components: so much to play with, so much to do. Then the wave of Hitec servos hit. Occupying nearly two-fifths of the box, they clued me in to the work ahead, but I was still willing, ready, and able. Everything about this kit is luxurious.

Assembly was almost seamless and took less time than I had originally thought. There were no surprises and things were reasonably illustrated and documented. The instructions are mostly clear and concise, but not preachy or pedantic. There were some ambiguities in the instructions, but they were easy to overcome.

The only difficulties I

encountered were a PEM nut that had damaged threads and a few missing pieces, like #2 washers. I decided to clear every PEM nut with a tap, just in case. I also decided to inventory everything and was able to rummage though my junk box and get what I was missing.

The core issues I have are also features in their own ways and they are the fairly limiting geometry that a 2 x 6 walker possesses, along with the simplicity of the processor — the BASIC Stamp II. In a way, this is sort of an equal match. The BASIC Stamp II isn't capable of the intense processing that is required to do the inverse kinematics that a 3 x 6 walker could use to more accurately walk, but I believe that it is also not necessary (more on that later, though).

Overall, this kit embodies the essence of what I think most of us see as the core of walking robots — lots of intricate, moving parts. While the simple 2 x 6 design and its processor are ill-suited for complicated kinematics, they do provide a great, simple start. A beginner should be able to jump into this right away and, in a few evenings, have a very high level of satisfaction. Additional third axis leg extensions can be added, along with an additional servo controller, as well, but, at that point, I would consider a processor with more horsepower to fully utilize the advanced geometry available.

Straight out of the box, this kit lacks the real complexity that I somehow thrive on, but I have to keep reminding myself that — just because I have been programming for 30 years and design insanely expensive motion control systems — not everyone else has or even wants to deal with that much wholesale madness.

Overall, a small degree of skill is necessary and be prepared to use some basic hand tools, as well as a 1/8" drill. I give this kit a solid A.

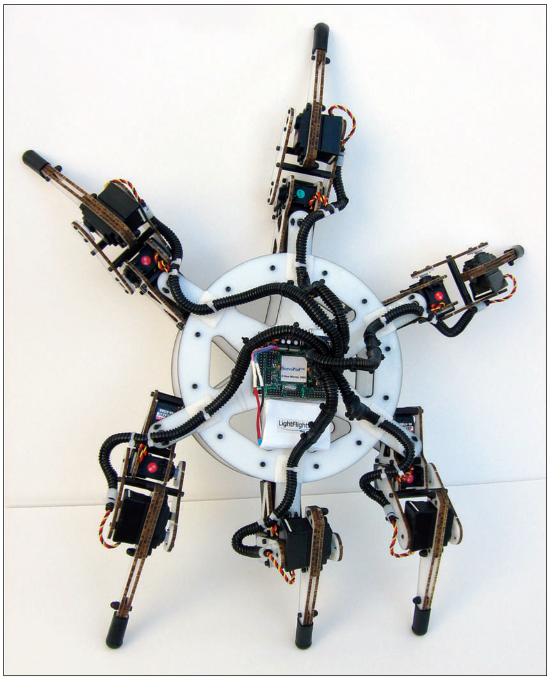
Extreme Hex 3R

Now, to kick things up a notch, I come to LynxMotion's EH3-R — Extreme Hex 3R.

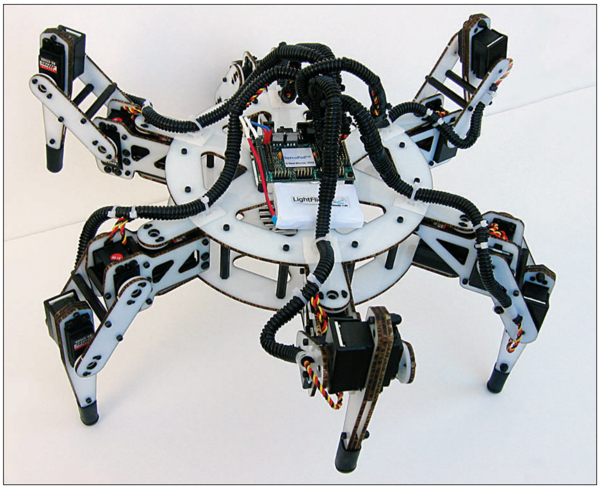
While the EH3-R lacks the refined presentation of the HexCrawler, it is a beast of a kit and very satisfying. Made of laser cut Lexan® (not just generic polycarbonate) and 18 Hitec HS475-HB servos, this kit is a formidable challenge. The resilience of the Lexan gives the EH3-R an almost meaty feel as you assemble it, as though it were going to lurch into life on its own. Replacing the clean gleam of the HexCrawler was the slightly acrid tinge of laser cut plastic, but that really adds to the feeling of elemental life that the EH3-R conveys as you build it.

In fact, the actual build was relatively easy. I only found myself wanting an easy way to secure the servo wires, but a trip to the electronics store solved that with a variety of fastened and adhesive-backed wire anchors. I would also like to get my hands on the metal standoffs that are now shipping with the kits, as I see myself accidentally breaking some of these eventually. I did take artistic license with the build geometry, making each leg identical, rather than mirrored images of each other, but more on that later.

The build of this kit is a lot more intensive than the HexCrawler, due to the additional six servos, but, in a way, it's a bit less complex due to the molded plastic pieces used to make



The EH3-R makes its escape.


The EH3-R shows its tripod gait.

the hinges. There is just a lot of repetition involved. The other difficulty I came into was peeling the protective plastic off the Lexan. It took me nearly an hour to accomplish this. Before peeling, I should have taken some time to clean up the laser-singed plastic cuts.

The three-jointed legs add another dimension to hexapod walking. With a two-axis leg, you get some scrubbing on the ground as the hip swings the leg fore and aft. You can mince about, taking little steps, but it is somewhat unappealing. Here, with the third axis and a lot of floating-point mathematics and inverse kinematics, you can start to calculate your path based on the geometry of the robot. You can set the ride height of the robot and trace the tip of the foot through a straight line or an arc to get much smoother walking. You can even crab-walk sideways.

The symmetrical design of this kit has always appealed to me in a hexapod, but it also opens the door for some interesting challenges. Take, for example, the standard 3 x 6 hex; it has two banks of legs: left and right, each leg on a side moving similarly, but out of phase with its leading and trailing neighbors. In effect, each leg mimicks the legs around it. The legs on opposite sides are mirror images, yet again, out of phase.

In short, there is a lot of symmetry. According to the instructions, that is how this kit is meant to be built. I however, decided to torture myself by building the kit without mirrored symmetry. I, instead, opted for a single axis of symmetry, with all of the legs built identically and simply moving as rotations of each other around the vertical axis.

What this means is that, by building and thus commanding each leg identically with no head or tail, the software is identical for each leg. There are no exceptions or reversing servos; each leg is a carbon copy of the others.

The commands that drive the legs will simply be coded as vectors — angle and magnitude — for the whole robot, and each leg will follow this path according to its position relative to the vector of commanded motion, not relative to the chassis. This means that there really is no “forward motion,” just crabbing. This can be further extended to arcing motions, where the whole robot follows an arc through space.

I chose to outfit this beast with a ServoPod from New Micros, Inc., both because the 18 servos do not even phase the 80 MHz DSP onboard, but also because the language onboard — IsoMax — was specifically crafted to run highly optimized floating point calculations.

My first shot at the software — written over the course of two evenings — employs a lot of interesting elements. The first is a 36 step, pre-canned gait. This gait pattern is non-scalar and can be offset from the body along the axis of the hip,

rotated in space, and scaled in both height and length. The phase of the gait can be rotated to perform different gaits, as well. This gait generator gets fed into the inverse kinematics engine, which takes the desired ride height of the robot, the desired position of the tip, and calculates the joint angles required to produce that tip position.

Overall, this kit gets an A, as well. I would like to see the pieces cleaned up somehow and see some provisions for anchoring the wires. A simple Allen wrench and pliers were all I needed to build it, but be prepared to spend some time programming, if only because there are 18 servos to deal with.

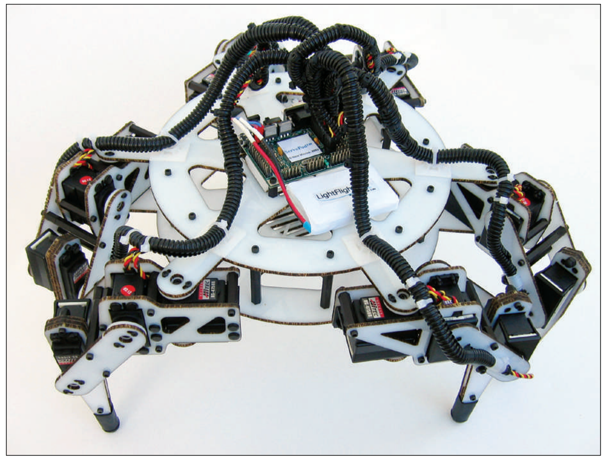
Shelob

Not content to leave well enough alone, Phil Davis — a consummate hobbyist by night and computer scientist by day — has realized that even three joints per leg leave a lot to be desired. To counter this, Phil has created Open Source Shelob (**www.IsoBots.com**).

I have been in this hobby for many moons, but I have never heard of a 4 x 6 before. The addition of the fourth joint allows for better joint positioning and trajectory tracking. It is like a 3 x 6 on adjustable stilts. In a 3 x 6, you have to accept that, as the tips of your feet translate through a line on the ground, you will generate a small amount of scrubbing unless you account for the geometry of the tip and, if you do, you generate waggle or bumping in the body. You are effectively constrained, not being able to adjust the angle of the last segment to the ground. The fourth joint allows this, but Phil wasn't even happy with that. He has also designed in an articulated, segmented body to better accommodate uneven terrain.

Shelob is constructed from 1/8" plywood from **www.Filener.com** This perfectly valid building material is easily cut, finished, and painted and is relatively inexpensive. People even build houses and boats out of the stuff and rumor has it that they used to build airplanes out of it, too.

What is especially important about Shelob is that her construction is open source in nature. By placing all the costs associated with the intellectual property into the public, everyone can benefit from the efforts of all who contribute. This should drive the quality up and the price down.



The EH3-R in its parked position.

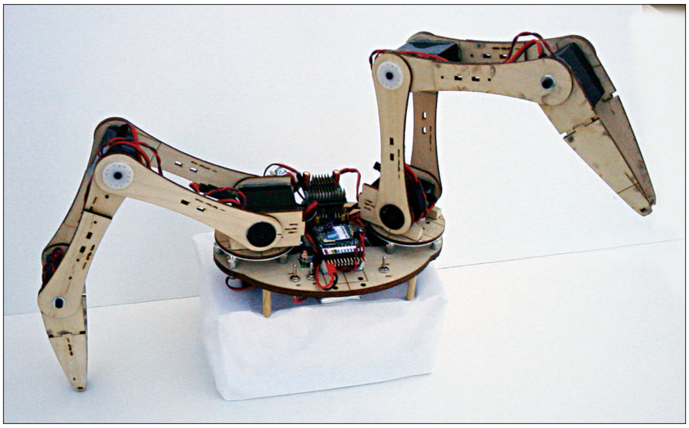
Phil's processors of choice are several IsoPods — one per segment — on a CANbus network. This will hardly task each IsoPod, but it will leave a lot of possibilities open for sensing by utilizing the extra timer channels and A/D converters. This can also remove some of the burdens of inverse kinematics from the main processor, which is meant to perform sensor synthesis and decision making.

Presently, the code is based on inverse kinematics, as well, but I know that the eventual goal is based on sensing, not calculating, though some forward kinematics will be useful for tracking the joints themselves through space. The code also includes velocity and acceleration profiling to keep things smooth and precise and — I guarantee — lots and lots of trig.

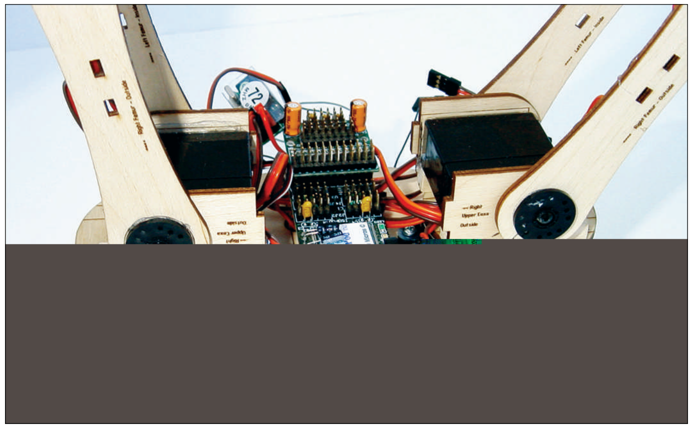
Walker Theory 102

Earlier, I alluded to not needing quite so complex of a trigonometry engine to perform walking. I believe the key to "real" walking is to

The HexCrawler kit is quite a spread!



One of Shelob's three segments.



Notice the details, like engraved pieces.

transcend past highly calculative methods and rely more on sensing — perhaps neural networks or simple pattern generators, modified by sensors. After all, if I use a trigonometry engine to generate a perfect gait, maintaining a uniform ground clearance and tracking a perfect plain, I am still moving to a pre-canned gait. Without being able to sense the feet relative to the terrain, any walking done will simply be a coincidence of the ground meeting my expectations.

To this end, Phil and I are working on three axis force sensors for the tips of the feet. This will allow us to sense the terrain and meter it; we can even use the sensors to provide feedback to sense whether the feet are tracking arcs or straight lines. By comparing the vector of the force sensed with the vector being generated by the motion of the leg, the shape of the surface can be ascertained.

A company called Bokam Engineering (**www.bokam.com**) makes some very nice three axis force sensors and amplifier boards. This would enable the measuring of lateral and vertical forces on the leg and accommodate the terrain. It would also allow the traversing of more difficult terrain (anything not flat) by feeling for obstructions.

An alternate method would be to use strain gauges on the spans between the joints themselves or metering the current consumption of each servo. These methods are more "integrated," but would then require you to do more kinematics to determine the vectors of force based on the values you sense and the positions of the joints. I will likely try this, as well, if only because it is complicated.

Through the method of sensing and reacting, rather than calculating, I believe simpler processors may be preferable, as they do not require as much high level math. In some ways, this is more in line with what my idea of a biological entity must be doing.

Please keep an eye open for full coverage of Open Source Shelob in the future. I hope to build one of my own out of carbon fiber rather than plywood. I also hope to fit it with strain gauges and may go to a custom board with a TiniPod, amplifiers, voltage to frequency converters for the strain gauges for each leg, and a single IsoPodX for a brain — but only if it is complicated. **NV**

Resources

LynxMotion — **www.lynxmotion.com**
CrustCrawler — **www.crustcrawler.com**
Parallax — **www.parallax.com**
Open Source Shelob — **www.isobots.com**
Filener — **www.filener.com**
Bokam Engineering — **www.bokam.com**

The Business of Electronics Through Practical Design and Lessons Learned

In The Trenches

Specifications

There is probably no other profession that depends upon specifications as much as engineering does. You create something to meet some set of requirements or you rely on the performance data of various components. Very often, both aspects are employed at the same time. Knowing how to make, read, and understand specifications is an important part of engineering.

Conflict of Interest

Arguably, the most important aspect of specifications to understand is their inherent conflict of interest to the company. Engineers want the most conservative specifications possible. This makes the product easy to produce, repair, and design.

Obviously, it's easier to make a 25 watt amplifier with 1% distortion than a 100 watt amplifier with 0.01% distortion, but who wants a 25 watt amplifier with 1% distortion? It won't sell. It's easy to make, but there's a small market.

On the other hand, there is a good sized market for the better amplifier. Clearly, there must be a balance between what people want and what you can make. Different companies have different points of view on this matter.

Hewlett/Packard (now called Agilent) is a good example. For decades, they have been recognized as producers of world class test instruments. However, in the 1980s and 1990s, their products became more and more expensive relative to the competition. There was no question that their quality was superb. However, would you spend $20,000.00 on an H/P oscilloscope when LeCroy would sell you one for $5,000.00 that did the "same thing?" The "same thing" was defined by the specifications. Suppose both machines were spec'd with a bandwidth of 500 MHz. Which one would you buy?

The truth is that the H/P oscilloscope was clearly better and every engineer knew it. The LeCroy 'scope was certainly good and it performed as specified.

However, the H/P performed better than specified. Yet, when the justification for the expense of an oscilloscope came, H/P had trouble competing. It's hard to convince financial administrators to spend four times as much for the "same" instrument.

H/P sales started to decline and their name became associated with "over-priced" test equipment. I suspect that this is a major reason behind the changing of their universally recognized name, which they worked so hard to get, in the first place. Agilent now sells test equipment that still is excellent, but it is more reasonably priced and specified.

Specifications are Not Black and White

It's important to realize that specifications are not always fixed, although specifications are — some-

times — pretty much outright lies. Way back when the number of transistors in a radio was significant, manufacturers would simply solder in non-functioning transistors to pad their count. Early stereo amplifiers used to be rated in "music power" watts. (This was, apparently, the maximum peak power reached just before the amplifier exploded.)

Currently, there is the ridiculous wattage rating of some computer multimedia speaker/amplifiers. I'm looking at one in the May 2004 catalog of a very well-known hobbyist electronics/computer supplier. These speaker/amplifiers are rated at 480 watts and cost $39.95. It's interesting to note that they look identical to mine — which are rated at 80 watts (also a joke). I took my speakers apart and found that the amplifier is a BA5406, which is rated at 3 watts per channel.

Note that I use one specification (and common sense) to contradict a different specification. This is not uncommon in engineering.

After all, a specification is just a measurement and measurements of the "same thing" can differ by method.

Let's look at a fictional — but realistic — example. You've designed a logic chip with a propagation delay of 5 nS. Suppose this is typical for this type of device. Your company wants a chip that's faster than the competition's. Can you accommodate your company without redesigning the chip?

How did you measure the propagation delay? You reply, "With the standard 20 pF load." Suppose you measured it with only a 10 pF load? That would reduce the apparent propagation delay.

Now, you have a chip with only a 3 nS delay. You've "improved" your chip considerably — with no increased expense. The company is happy, marketing is happy, and you get a raise.

People continuously find loopholes in standard measurement techniques in order to give their product a perceived advantage in the marketplace. This is called "specsmanship." While it's not really good engineering practice, it's fairly common in marketing (again, engineering vs. marketing).

You clearly show on the spec sheet that all measurements were with a 10 pF load, so you are being completely honest. Nowhere is it said that your chips are faster than the competition's. If those companies choose to use 20 pF to measure their chips, that's their decision. You have presented your measurements and how you obtained them. It is up to the consumer to determine if your product will suit their needs.

This illustrates the constant tug-of-war between engineering and marketing. Engineering likes standard methods so that measurements are easy and consistent. Marketing wants a product that stands out so it will sell. It's important to see that both points of view are valid. There is nothing unethical about making your product look good. There is nothing wrong about emphasizing the strong points and down-playing the weak points, but it is also important to realize that, in this case, your chip is really no better than the competition's. If you compare your chip in the same circuit as your competitor's do, they perform the same.

Two Types of Specifications

There are two general types of specifications: performance and target.

Performance specifications are those that the product is guaranteed to meet (hopefully).

Target specifications are those that the product is designed to meet.

Engineers usually define the performance specifications. Marketing usually defines the target specifications. Generally, these target specifications are based upon feedback from customers who say that they need a product that does "___." It's important to keep these types of specifications in their proper place.

Unfortunately, too few engineers understand target specifications. All they see is that marketing has committed them to create a product with

specifications that are mutually exclusive. Marketing replies that this is what the customer wants to buy. If we can't provide it, someone else will.

As you can see, specifications are the weapons that the engineering/marketing war is fought with.

Instead of arming the photon torpedoes and targeting marketing, what can you do when faced with impossible target specifications? First, calm down. Remember, marketing is not engineering. Their idea of specifications is not the same as yours. It's really a different word and concept. They're simply repeating what the customer wants. Often, they've combined requests from different customers into a single product and it may simply be that they haven't reported the specifications accurately. Remember the three laws of selling:

1. Marketing is not engineering.

2. Marketing has a potential sale.

3. Everything in marketing is negotiable.

Turn Lemons into Lemonade

Suppose you are given an impossible task. Let's say that marketing has promised a client a product that can measure temperature from 0 to 200 degrees F in 0.1 degree intervals using one of your standard products that has a simple, eight-bit processor.

Unfortunately, the processor only has an eight-bit A/D (analog-to-digital converter). You need 2,000 steps (200 degrees by 0.1 degree intervals) and the A/D only provides 256 steps. It's impossible to do! (Actually, it may be possible if you employ the statistics we discussed a few months ago.)

First, calmly examine the problem in detail. Then, create your best design. In this case, let's say that you feel that an outboard 12-bit A/D is necessary. Price the system with the new A/D. You may need to create a completely new product because the existing one can't be modified. That may be an absurd approach, but examine it anyway. Try to anticipate every comment, criticism, and observation that marketing can make. Have a good answer for each and every one. Then call a design review.

In this review, explain in simple terms what impact the requested specifications have on the existing product and then present your design. Always have a workable design to present. It may not be cost effective or practical, but it is politically necessary. If you simply object to the design, you'll be considered an obstructionist.

If you provide an alternative design, you will be seen as a team player. They may complain about the cost or the delay or the form factor, but, if you have clearly explained your position and provided a design that meets the specifications, you will be seen as trying to help.

***Note**: You should generally just present your new approach. Let the questions lead you into comparing the new and old designs. Non-technical people generally find this easier to follow, but be completely prepared with graphs, tables, etc.*

It often happens that, during this design review, new information or specifications emerge. In this example, the reason for 0.1 degree accuracy was because the product was to be used for measuring the body temperature of animals in a zoo. Since very few warm-blooded animals have a body temperature below 85 degrees and above 110 degrees, the eight-bit A/D can provide the 0.1 degree resolution required (256 steps in 0.1 degree increments gives a 25.6 degree range).

Did you notice that we're talking resolution rather than accuracy? They are two entirely different specifications.

Unfortunately, they are often confused. The resolution of a system is its ability to separate close measurements. In this case, it's 0.1 degrees. The accuracy is the ability to measure according to a standard. This has not been discussed at all here.

Many inexpensive temperature sensors have an accuracy of ±2 degrees. A reading of 100 degrees may actually be anywhere from 98 to 102 degrees. Obviously, this is not very good for determining if a baboon has a fever.

Therefore, a special thermistor will be needed. Understanding the difference between accuracy and resolution specifications is critically important in engineering.

***Note**: It is not unheard of for an engineer to identify "impossible" specifications at a design review while having a solution already in hand. This solution may or may not be presented at that meeting.*

However, sometime soon, that engineer will "realize" that such a solution exists and provide it to the surprise and delight of all involved. This saves the company time and money. It also improves the engineer's reputation. Theatrics and good timing are not unethical.

Hard and Soft Specifications

How long a battery will last in a heart pacemaker is a hard specification. How long a battery will last in a boombox is fairly soft. It's surprising how often engineers fail to consider this aspect. Not all specifications are created equal. Making sure the multimeter measures the correct AC voltage at 60 Hz is important because that's the frequency that is most commonly measured. If the multimeter is off by 5% at 250,000 Hz, it's not as important. Most users would rather have a meter that measures 60 Hz accurately and 250,000 Hz with 5% error than a meter that was off by 2.5% across the frequency range.

Obviously, the most important — or hard — specifications are those pertaining to personal safety. It is critical that these specifications always be conservative. What is the AC leakage current? Is the fuse rating correct? (Do you know how to properly choose a fuse?) The two greatest personal hazards electrical engineers need to consider are electric shock and fire hazard. They should always be considered in every design — even in battery-operated products.

Suppose you have to design a simple linear power supply — just a transformer, rectifiers, and a filter capacitor. It's easy, right? It should be, but it doesn't seem to be. You need 18 volts DC at 750 mA, so you choose a 24 VAC transformer that provides 2 amps, to be conservative. The filter capacitor should be conservatively rated. Let's add 50% over the 24 volts and use a 35 volt filter capacitor. That seems reasonable, right?

Wrong — possibly dangerously wrong! The transformer is rated in RMS voltage and under full load (2 amps). Multiply the 24 volts by 1.414 to get the peak voltage. This comes to 33.9 volts. Add about 10% to compensate for the loaded voltage drop and the unloaded peak voltage out of the transformer is 37.3 volts. The filter capacitor is really a bomb waiting to explode (and they do!). The absolute minimum voltage for a filter capacitor is twice the transformer voltage. In this case, that's 50 volts. To be conservative, 63 volts or more is needed.

The rectifiers can be 1 amp types, right? After all, we're only drawing 750 mA. Again, wrong. The transformer is rated at 2 amps and can provide considerably more for a short time. At power-up, the capacitor acts like a short circuit until it gets charged up, so the inrush current will be over 2 amps. The larger the capacitor, the worse this problem is.

Admittedly, rectifier diodes are pretty rugged and can take substantial inrush overloads, but this is still not a conservative design choice. (An inrush-limiting resistor can be a simple and effective solution.)

Of course, the transformer doesn't have to provide 2 amps. A 1.0 amp or 1.2 amp transformer could be considered. It will also be less expensive.

There are a number of points here. A conservative transformer choice (2 amps) makes other parts of the design non-conservative. The specification of an RMS voltage (24 VAC) is not the specification of a peak voltage (37.3). Safety requires the full understanding of every detail. Cutting corners or carelessness is simply unacceptable when safety is involved.

It is also interesting to note the dance between target specifications and performance specifications. We make our design meet our target specs by choosing parts with proper performance specs. When we're done, we'll have a product with performance specifications. Further, our product may be used in another product to meet its target specs and so forth and so on.

Software Specifications

First, stop laughing. There is some truth in calling software specifications an oxymoron. If you don't believe this, read Microsoft's "End User License Agreement." It is truly educational.

With software, if it works, then it meets specifications. There is no easy way to determine if standard engineering practice is employed. There is usually no outside review of the actual code. This is very different from hardware. A circuit board must not only work, but must meet specific design rules (AKA specifications) in regard to parts placement, layout, trace widths, trace spacing, hole size, and so forth.

There are no equivalent rules for software. There should be. There have been attempts to analyze code with software, but this has not been generally accepted, nor, as I understand it, is this software particularly good.

The target specifications for software become its performance specifications.

However, these are not the same. The target specs say what the product must do. The performance specs say how well it must do it. I have never seen actual performance specifications for software, with the exception of benchmark ratings. The only way to compare similar software packages is to actually try them, side-by-side.

Objective software standards are not impossible to create or measure. How about measuring the ratio of branch to in-line statements or a code-line to comment-line ratio? What about providing the number of standard library code-lines and the number of custom code-lines? These values would allow the comparison of one program to another. It seems to me that they would be useful to have.

Unfortunately, I don't see this happening soon.

The Root of All Legal

One of the most common sources of customer complaints and legal action is because the customer feels that the product doesn't meet specifications: This clock doesn't keep time. The radio doesn't pick up my favorite station. The air conditioning doesn't keep the whole office cool. I want my money back!

There will always be unhappy people. However, your product shouldn't make them that way. Properly specifying your product can go a long way in reducing these complaints.

Additionally, good specifications

can educate the user about what to expect from your product. Remember, unfulfilled expectations are probably the biggest source of customer dissatisfaction.

Put yourself in the your customer's place when you write the specifications. What would like to see? What's important to you? At the minimum, the spec sheet should include what your product needs to work (the voltage, frequency, and power), what the product produces (output power, distortion, etc.), proper operating conditions (loads, environment), operating limits (frequency range, bandwidth, power output, etc.), and the physical characteristics (dimensions and weight). Always include notes about other equipment needed for operation (AC adapter, blank disks, computer requirements, etc.).

Next, you can provide the softer specifications. Sometimes, these are called "typical" specifications and are more like guidelines rather than guaranteed performance. An example is the highest frequency that an AC voltmeter can reliably measure. These may not be absolutely necessary for the customary use of your product, but they are informative and useful to know.

Don't overspecify your product. You don't want to create problems. Say things like "high brightness LED display," instead of "2,000 MCD LED display."

In the future, it may be that 3,000 MCD displays are the same price or that cheaper 1,000 MCD displays are necessary for cost. Think carefully because the spec sheet may outlast your involvement in the product.

There is nothing inherently unethical or improper about omitting a bad specification. (It is unethical and improper to include a false specification.)

For example, if the frequency response of your voltmeter only goes to 100,000 Hz and all your competitors' go to 250,000 Hz, you may choose to omit it. You want your product to sell. You are not forced to identify every weak point in the design (except for safety, of course). Naturally, if it's a major specification, it will be noticed and it will cause problems.

Conclusion

Specifications are used in designing, defining, and comparing products. There are different types and definitions of specifications, so it's useful and important to understand them. Since your job and your company's health depend on specifications, using, creating, and properly reading them is vital. **NV**

Putting the Spotlight on BASIC Stamp Projects, Hints, and Tips

Stamp Applications

No More Coffee Spills

Ideas more crazy than this have become successful products!

Have you ever noticed yourself when you've noticed yourself? I seem to do it all the time, suddenly noticing some behavior I had that — until that very moment — had been completely unconscious of. Often times, the thing I notice is quite humorous. Like most humans, I'm a creature of habit. My typical daily habit is to wake up, check Email quickly (in case there's been an overnight customer emergency), jump on the treadmill for about 30 minutes, grab a bite to eat, and then pop by the neighborhood Starbucks for a cup of coffee and a quick chat with a very pleasant lady named Lindsay.

On a recent return trip from Starbucks, I noticed myself doing something that actually made me laugh. While steering with my left had, I would reach down with my right hand to adjust the coffee spout such that coffee would not slosh out while I was cornering. Honestly, I laughed out loud, then immediately thought that, if I had an accelerometer, a stepper motor, and a BASIC Stamp, I could keep both hands on the wheel. An idea was born ...

Was it a practical idea? Well, probably not — and I'm certainly not going to tear apart the center console on my new SUV to install such a device — but the exercise in designing the circuitry and code to solve my coffee sloshing problem is still worthwhile. I receive a lot of Emails asking how one gets "so good" at programming the BASIC Stamp microcontroller. Like getting to Carnegie Hall, it takes practice, practice, practice. Imagine how many tens of thousands of practice shots Michael Jordan shot before and during his career; every one of them served to prepare him for all those championships. I guess my point is not to wait for a "real" project to improve your programming skills. Many times, it's worth doing a project just for the experience of doing it.

Leaning To and Fro

If you're new to the BASIC Stamp microcontroller or weren't around for my article in the November 2003 issue on using GPS, you may be wondering how we're going to take the output from an accelerometer and use it to point the spout of a coffee cup lid.

To be honest, it's dirt simple: We're going to use the **ATN** function. **ATN** (arctangent) returns the angle (in binary radians: 0 to 255) that points to the intersection of two vector values.

The first thing to do, then, is to read the accelerometer outputs (x and y axis) to establish the g-force vectors. You may remember from our previous work with the MEMSIC 2125 that a 0g output is a five millisecond pulse. Negative g-forces are shorter than five milliseconds; positive g-forces are longer. Reading the pulse outputs is no trouble; we can use **PULSIN** to do it. Here's the trick: The resolution of **PULSIN** gets better as BASIC Stamp modules get faster. Code that will work properly with a BS2 module will not return the correct results when using the BS2p.

You know where I'm going with this: conditional compilation. I covered it briefly in the past and I think it's good to remind ourselves that this feature is now available in the Version 2.1 compiler. So, what are we going to do

Figure 1. Memsic 2125 Connections.

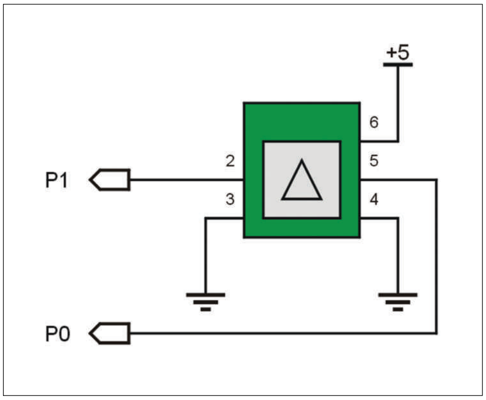
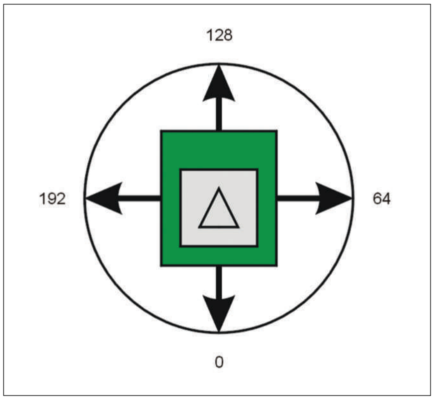


Figure 2. ATN Output.



with it? We're going to use a conditional compilation construct to set a constant value that will be used to scale the raw input from **PULSIN** to microseconds, always returning the correct value, regardless of which BASIC Stamp module is being used.

```
#SELECT $STAMP
  #CASE BS2, BS2E
    Scale       CON      $200
  #CASE BS2SX
    Scale       CON      $0CC
  #CASE BS2P
    Scale       CON      $0C0
  #CASE BS2PE
    Scale       CON      $1E1
#ENDSELECT
```

When we compile a program, the first thing that the compiler does is look for conditional compilation symbols (created with **#DEFINE**), then look for conditional compilation constructs like ours above. The construct works as we'd expect, but only at compile time. The section that evaluates as true will get compiled into the program; all others will be ignored.

If, for example, we had selected a BASIC Stamp 2 module, our program would compile and assign the constant called Scale a value of $200 (same as 2.0 decimal when used with */).

Once you get used to conditional compilation, it can be a very powerful tool. How many times have you sprinkled **DEBUG** statements through a program, only having to go rip them all out when everything is working? With conditional compilation, you can do this:

```
#DEFINE DebugMode = 1
```

Then, in the body of the program, we add a bit of logic around our **DEBUG** outputs:

```
#IF DebugMode #THEN
 DEBUG "Program Status"
#ENDIF
```

Once the program is working properly, we can turn-off all the **DEBUG** statements with one small change:

```
#DEFINE DebugMode = 0
```

How much easier is this? Also, as we've all seen, programs are ultimately updated. When that happens, we don't have to go back through and drop in **DEBUG**

statements to check on our updates — we simply re-enable the ones that are there with **#DEFINE**.

Okay, let's get back to reading the accelerometer (connections are shown in Figure 1). The first thing to do is scale the raw input from it to a known value. By using our Scale constant, we will end up with microseconds and at 0g on either axis, we should get around 5,000 (five milliseconds).

Remember that the */ operator works like multiplication, with the parameter being expressed in units of 1/256. This lets us multiply by fractional values between 0 and 255.996.

```
Get_Memsic:
  PULSIN XPin, 1, xG
  PULSIN YPin, 1, yG
  xG = xG */ Scale
  yG = yG */ Scale
  RETURN
```

If we run this code in a loop and look at the results, we'll see values that range from 3,800 to 6,200 microseconds. Okay, but what we need is something that fits into the -127 to 127 range required by **ATN**. It's actually very easy and uses the "round up" math we learned as kids in math class.

```
Get_Memsic:
  PULSIN XPin, 1, xG
  PULSIN YPin, 1, yG
  xG = xG */ Scale + 50 / 50 - 100
  yG = yG */ Scale + 50 / 50 - 100
  RETURN
```

Right after Scale, you'll see "+ 50 / 100." This rounds up the value and scales it down to 50 as the 0g point. Then, we subtract 50 so that 0g returns a zero value. There's an important note here: We need to do the subtraction last because, if we attempt to divide a negative number, we will get incorrect results.

If we look at the output now (using the SDEC modifier, of course) we should see values from -12 to +12. Don't be worried about the apparent loss of resolution of our vector. The reason we've divided down so much is to eliminate minor jitter from the sensor that would just cause the stepper to quiver back and forth unnecessarily. What we've done, in fact, is a bit of simple digital filtering.

Okay, now that we can read the output of the accelerometer as vectors that will work with **ATN**, let's map the output of **ATN** vis-à-vis the g-force loading on the sensor. Figure 2 shows the values I read from my

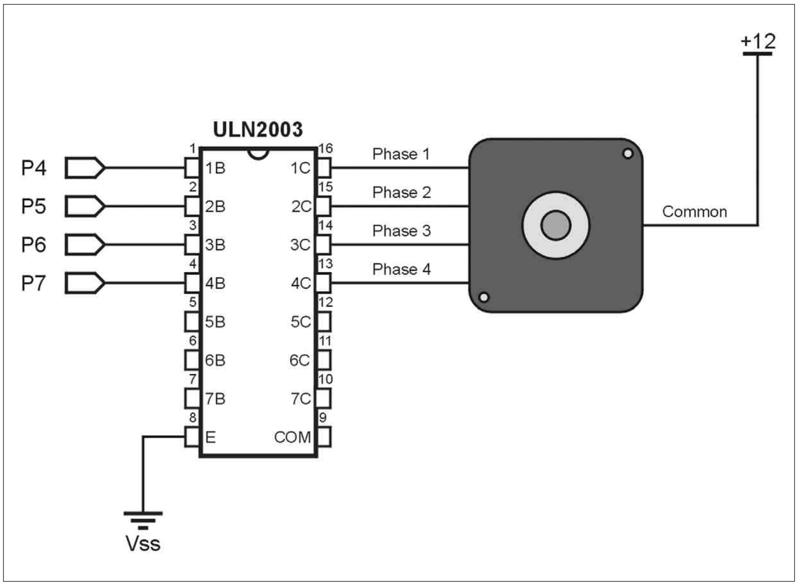


Figure 3. Stepper Connections.

setup. We can simulate acceleration of the car by tilting the front end of the sensor (pins 1 and 6) up. We can simulate braking by tilting the front end of the sensor down.


```
Main:
  GOSUB Get_Memsic
  DEBUG HOME,
        SDEC xG, CLREOL, CR,
        SDEC yG, CLREOL, CR,
        CR,
        DEC (xG ATN yG), CLREOL
  PAUSE 200
  GOTO Main
```

So, under simulated acceleration, we get zero, under braking, 128, turning right, 192, and turning left, 64. Let's think about this for a moment. Wouldn't it be a bit more convenient if the output matched the number of steps of our stepper motor? It might be easier to deal with, mentally, if the values increased in a clockwise direction, as well.

I happened to grab a stepper that has a 3.6 degree step; this means that there are 100 steps in each revolution. Here's how we can do it:

```
angle = 100 - ((xG ATN yG) */ 100) // 100
```

This may look a bit convoluted, but I promise there is a reason for every bit of it — let's work from the inside out. By using */ (star-slash) with a parameter of 100, we scale the output of **ATN** from 0–255 to 0–99. Our next issue, then, is reversing the direction so that values increase going clockwise instead of counter-clockwise, as they do now. By subtracting from 100, we're able to do that — with one tiny glitch: what was 0 ends up being 100. Okay, then, we can use the modulus operator on the whole works and now our output is 0 to 99.

Accelerating means we should point the coffee spout toward 0 (front of car); when braking, it will point toward 50 (rear of car), to 25 when turning right, and, when turning left, 75. Let's polish off our main loop:

```
Main:
  GOSUB Get_Memsic
  angle = 100 - ((xG ATN yG) */ 100) // 100
  IF (angle <> pos) THEN
    GOSUB Move_Spout
  ENDIF
  GOTO Main

  END
```

This is as simple as it gets: we read the new angle and compare it to the current spout position. If there's a difference, then we reposition the spout; otherwise, we go read the accelerometer again.

Before we can actually turn the spout, we need to find the shortest path between the current position (pos) and the new position (at angle). It actually took me a few minutes to figure out how to code this one cleanly. While it

looks simple on paper — with circles and dots — it takes a bit of thinking. Let's look at the code that determines rotational direction and work through it:

```
Move_Spout:
  IF (angle > pos) THEN
    span = angle - pos
    IF (span < HalfRev) THEN
      stpDir = MCW
    ELSE
      stpDir = MCCW
      span = RevSteps - span
    ENDIF
  ELSE
    span = pos - angle
    IF (span > HalfRev) THEN
      stpDir = MCW
      span = RevSteps - span
    ELSE
      stpDir = MCCW
    ENDIF
  ENDIF
```

Here we go: If the new angle is greater than the current position, then we get the span by subtracting the old position from the new. Next, we check to see if that span is less than half a revolution. If it is, then we set the stepper direction to clockwise; otherwise, it will rotate counterclockwise.

Notice that we have to make a correction in the span if we determine that the shortest path is counter-clockwise. If we don't make this correction, the spout will overshoot the desired position. We can use a similar set of logic when the new angle is less than the current position — with adjustments, of course, to make sure that we turn in the direction that provides the shortest path.

Okay, let's finish up and actually reposition the stepper motor:

```
  stpDelay = MoveTime / span

  DO
    stpIdx = stpIdx + stpDir // 4
    READ (Steps + stpIdx), Coils
    PAUSE stpDelay
    span = span - 1
  LOOP WHILE (span > 0)

  pos = angle

  RETURN
```

The rest of the subroutine starts by calculating the delay between steps. The value is set by dividing the total movement time (500 ms in our program) by the number of steps in our move. Note that we must have some delay; the stepper motor needs it. Also, we'll want to experiment with this a bit. The largest possible move is half a revolution. Setting the time for that move to 500 milliseconds seems reasonable — fast enough to get there swiftly, but not so fast as to sling coffee out of the spout.

A **DO-LOOP** is used to send the step data to the motor. We're back to our old tricks with the modulus operator; this allows us to set the direction with a variable. The coil data is pulled from a **DATA** table with **READ** and placed right on the pins. Of course, we cannot drive a stepper directly with BASIC Stamp IO pins; we need a high-current buffer to handle the coil load. Figure 3 shows how to use our old friend, the ULN2003, to handle the load for us. Finally, we need to update the pos variable with our new position and start the whole process again.

Short and Sweet Rules!

Okay, I know this project wasn't a big mental challenge, but I do think it's useful — even if we don't automate our car's cup holder. I'm sure you'll figure out something fun to do with it and, when you do, don't hesitate to share your results with me.

Until next time, Happy Stamping. **NV**

Resources

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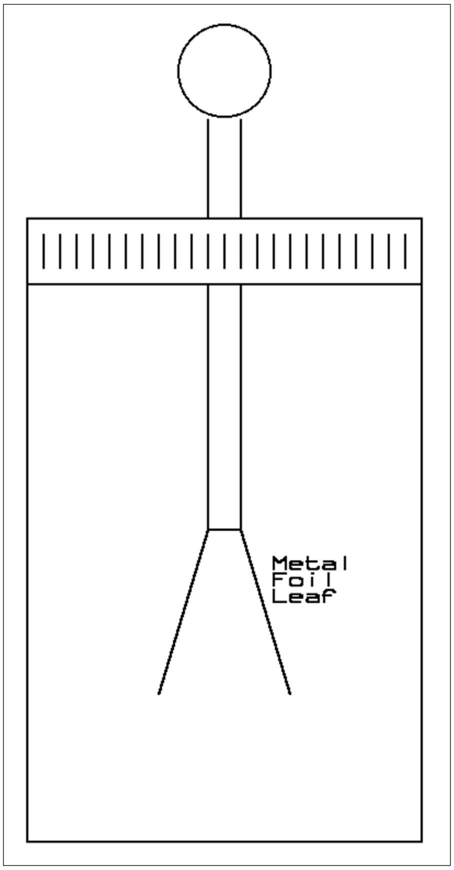
Approaching the Final Frontier

Near Space

The History of Cosmic Rays

The study of electrostatics was our first step in the field of electronics. In electrostatics, electric charges are relatively stationary. So, the natural philosophers (early scientists) who studied the phenomenon of electrostatics concentrated primarily on the creation, storage, and interaction between the two types of electric charges. One of their tools was the electroscope, a device consisting of two metal foil leaves draped over a metal rod and protected within a glass jar.

Figure 1. The electroscope.



The electroscope indicates the presence of electric charges by the spreading of its two metal foil leaves. The presence of charges of the opposite polarity is indicated by the collapse of the previously charged leaves. If no opposing electric charges are present, the leaves should remain spread apart after their initial charge.

Instead, it was discovered that, once charged, the leaves of the electroscope did not remain charged. The electroscope slowly loses its charge — no matter how dry or clean the air. The source of this discharge was unknown.

Viktor Hess' Experiment

On August 7, 1912, physicist Viktor Hess began making balloon flights with electroscopes onboard. In his flights, he rode in an open gondola under a hydrogen filled balloon to altitudes in excess of 15,000 feet. The experiments were not without risk. The hydrogen in his balloons was flammable and, at high altitudes, he found that there was less oxygen to breathe and that the air would begin to get cold.

On these flights, Hess discovered that his charged electroscopes would discharge more quickly at higher altitudes. The effect became apparent once his balloon climbed above 6,000 feet and the interference caused by natural radiation emitted by the ground.

Hess' electroscopes discharged more quickly because the air was a source of ions that neutralized the charge on his electroscope. Since the electroscope discharged more rapidly at higher altitudes, he concluded the ionization of the atmosphere increased as he rode higher in his balloon.

The increase in ionization with increasing altitude indicates that the ionization is caused by an extraterrestrial source. In other words, there was a source of radiation in space that was ionizing molecules in the atmosphere and causing his electroscopes to discharge. This same source of radiation was also discharging electroscopes on the ground, but more slowly than in his balloon experiments.

In 1936, Hess was awarded the Nobel Prize for his discovery of cosmic rays, the extraterrestrial source of radiation. Cosmic radiation was a fascinating topic for people in the last century. As I recall, there is even an old black and white Frankenstein movie that mentions cosmic rays as being responsible for the origin of life on Earth.

Initially, it was believed that cosmic rays were a form of electromagnetic radiation, like microwaves or gamma rays. Electromagnetic radiation is carried by photons, which are particles without rest mass or electric charge. Photons are not affected by magnetic or electric fields.

However, since cosmic rays *are* affected by magnetic and electric fields, they must consist of charged particles, like electrons and protons.

It took several decades to straighten out this error in books written for the general public. I can recall seeing cosmic rays listed at the high end of the electromagnetic spectrum in high school science materials. Because of this cosmic

error, I got burned when correctly answering a question about the electromagnetic spectrum during tryouts for the College Bowl in 1981.

Cosmic Rays as a Tool of Science

The first particle accelerators were built less than 100 years ago. These first generation devices couldn't reach very high energies.

So, to study subatomic physics, physicists launched their experiments in high altitude balloons, where they could use cosmic rays as their source of high energy subatomic particles. The results of these experiments led to the discovery of several important subatomic particles.

One subatomic particle discovered in cosmic ray experiments was the meson. The meson was predicted to exist and be responsible for holding the nucleus of the atom together. There are actually several types of mesons — like the mu and pi mesons (called the muon and pion) — and only one is responsible for keeping the protons inside the nucleus together. As it turns out, the first meson discovered was not the one found inside the nucleus. Another particle discovered from cosmic ray experiments was the first anti-matter particle — the anti-electron or positron — which was predicted by physicist Paul Dirac.

Today, particle accelerators can reach such high energies that it's no longer convenient to do subatomic research with cosmic rays. However, that doesn't mean cosmic rays are no longer an item of research. Now, cosmic rays are researched in an effort to understand astronomical and nuclear processes occurring in the Sun and beyond the solar system.

The Nature of Cosmic Rays

Their Composition

The vast majority of cosmic rays are energetic nuclei — high speed atoms stripped of their electrons. About 86% of cosmic rays are protons or hydrogen nuclei (remember, the hydrogen nucleus doesn't have a neutron). Twelve percent are helium nuclei (alpha rays), 1% are energetic electrons, and the remaining 1% are atomic nuclei heavier than helium; these are elements that astronomers call metals. There are some high energy gamma rays and neutrinos thrown into the mix, as well.

Their Energies

One of the most amazing aspects of cosmic rays is their level of kinetic energy. Some cosmic rays carry over 100 quintillion electron volts of energy. That's enough energy to boil a thimbleful of water if all that energy could be transferred to it. (In reality, such a cosmic ray would travel right through the water, scarcely noticing it, and leave only a tiny bit of its energy in the water.)

Put another way, this amount of energy is the same as the kinetic energy of a baseball thrown at about 100 mph! Imagine the energy of a fast baseball packed into a single, invisible proton. The high energy levels found in cosmic rays allow them to make the trip to Earth at speeds very close to that of light.

The Source of Cosmic Rays

In optical astronomy, astronomers can point their telescopes in the direction of the light they are observing and see the light's source. However, galactic, solar, and terrestrial magnetic fields so thoroughly mix up the paths of cosmic rays that other methods must be used to determine their source. The possible sources of cosmic rays are determined by how they respond to the solar cycle, their composition, and their kinetic energy. So far, it's believed that there are three sources of cosmic rays.

Solar Cosmic Rays

These cosmic rays originate with the solar chromosphere (the solar layer above the photosphere — the visible surface of the Sun) during high energy events like solar flares. Solar cosmic rays tell us the types of elements and their proportion residing in the outer atmosphere of our Sun.

These tend to be the lowest energy cosmic rays. Their presence goes up shortly after a flare and can increase by a factor of hundreds to

even hundreds of thousands. Such events can last for only a few hours or several days. Solar cosmic rays represent a hazard for astronauts traveling outside of the Earth's protective magnetosphere. Fortunately, our Apollo astronauts made their lunar expeditions during a time of solar quiet.

Anomalous Cosmic Rays

These are the nuclei of difficult to ionize atoms. They originate as neutral atoms drifting into the solar system from interstellar space. When exposed to solar ultraviolet radiation, these atoms become ionized. Once ionized, the solar wind can capture them and carry them away from the solar system. When traveling with the solar wind, these ions are called "pickup ions."

Pickup ions are carried to a point where the solar wind is forced to slow down from supersonic to subsonic speeds by the resistance of the local interstellar medium. This region — where solar wind flow goes from supersonic to subsonic — is called the terminal shock. Smaller versions of terminal shocks are seen within the solar system when the solar wind plows into the magnetosphere of planets.

The passage through a terminal shock can accelerate pickup ions and change their direction of travel. After multiple passes through the terminal shock, these cosmic rays can break free and travel back into the solar system, where they can be detected. The remaining, anomalous cosmic rays escape the solar system and travel between the stars.

Anomalous cosmic rays have intermediate energy levels and are representative of the atoms found in nearby interstellar space. They are influenced by the 11 year solar cycle, which changes the location of the Sun's terminal shock.

Galactic Cosmic Rays

These cosmic rays are the highest energy cosmic rays we find. They are fully stripped of their electrons. Galactic cosmic rays probably originate in supernova remnants, which are the expanding clouds of gas and dust that were once the outer layer of a massive star. The explosion itself didn't create the cosmic rays. Instead, the powerful and expanding magnetic fields and shock waves associated with supernova remnants accelerate ionized atoms.

After the ions pick up enough energy, they can escape from the supernova remnant as galactic cosmic rays and travel interstellar space. We know supernova remnants can accelerate charged subatomic particles because the radio signals the remnants emit indicate the presence of powerful magnetic fields that are accelerating electrons.

When the charged electron accelerates, it emits a radio wave called synchrotron radiation. The study of the isotopes found in galactic cosmic rays and their half lives indicates that these cosmic rays can travel for several million years before being detected on Earth.

Most galactic cosmic rays have low enough energies that the Milky Way's magnetic field bends their paths around a radius smaller than the galaxy. This effectively traps these lower energy galactic cosmic rays within the Milky Way galaxy. However, a small percentage of the galactic cosmic rays contain more energy than is available in supernova remnants.

Their energies are too great for them to be held within the galaxy's magnetic field. So, these ultra-high energy cosmic rays must originate outside the galaxy. However, these high speed cosmic rays cannot travel for long through intergalactic space before their collisions with photons left over from the Big Bang (the cosmic microwave background) significantly lower their energies.

It's believed these ultra-high energy cosmic rays originate in nearby, active nuclei galaxies, which appear to be powered by massive black holes. Perhaps, instead, these cosmic rays are trying to tell us about exotic physics occurring deep within intergalactic space.

One of the benefits of galactic cosmic rays is that their collisions with atoms in interstellar gas create some of the rare elements needed for life, but that are not synthesized by the fusion reactions within the stars.

Detecting Cosmic Rays

Geiger Counters

The easiest way to detect the

The Near Space Email Group

In an effort to share current information with this column's readers, I have created an Email distribution list under Yahoo! Groups. My Email list is not designed to replace the many lists for amateur near space groups that already exist. I plan to make announcements, update column information, and answer reader questions in this list. I will also keep subscribers up-to-date on the status of my book on amateur near space exploration.

To join the Near Space Email group, go to **http://groups.yahoo.com/**

Sign in if you're already a member of Yahoo! — if not, click under New Users, then Click Here To Register.

Under the Join a Group field, type NearSpace and then press Enter.

Under the list of groups displayed, click NearSpace (it will be the only group listed).

In the upper right of the screen, click to join the group.

I hope you find the Email list useful in your efforts to begin your own program of amateur near space exploration.

presence of ionizing radiation is with the Geiger counter. The electronics in the Geiger counter create a difference in charge between the walls and the central wire of the Geiger-Muller (GM) tube. The gas inside the GM tube cannot discharge this potential difference unless the air becomes ionized. The passage of cosmic rays is just what the air inside the GM tube needs to create an ionized channel.

Once the gas inside the GM tube becomes ionized, electrons begin traveling across the tube, further increasing the level of ionization inside the GM tube and creating a small current that is amplified to become the familiar click of 1950s B-grade science fiction movies. (Ah, the classics!) Gases inside the GM tube eventually quench the ionization inside it. If it wasn't for the quenching gas, the ionization would continue, preventing the detection of another cosmic ray.

The time it takes to quench a GM tube is called its dead time. The dead time for the GM tubes I use in my cosmic ray experiments is 90 microseconds. As long as there is at least a gap of 90 microseconds between cosmic rays, my GM tube will detect them all. This means that, on an average, I can detect a flux greater than 11,000 cosmic rays per second with my Geiger counter.

There are several limitations with Geiger counters. The first is that Geiger counters cannot measure the energy of each detection, so my Geiger counter experiments only detect the increased cosmic ray flux as a function of altitude and not the changing energy of each detection.

Another limitation is that Geiger counters cannot indicate the direction of travel of a cosmic ray. In my experiments, I have no way of determining if the cosmic ray flux is truly uniform in nature. One last limitation to mention is that Geiger counters cannot indicate which type of subatomic particle was detected. My cosmic ray experiments cannot tell me if the composition of cosmic rays changes during the experiment.

That said, there are some tricks to get around these limitations and I'll discuss them in a future column. (I've been experimenting with one of them.)

Photographic Film

Some early cosmic ray experiments carried stacks of photographic film with thick emulsion between sheets of lead. When a cosmic ray collided with a lead atom, it created a shower of secondary cosmic rays that left dark streaks in the developed film. The photographic film stack was placed between the poles of a magnet.

From the dimension and direction of curvature of the streaks found in the emulsion, the type of particles created in the collision was determined. I get the impression that grad students were the ones searching through the photographic stacks with a microscope and determining the composition and energy of their cosmic ray prey.

I didn't understand how photographic stacks were made up when, in 1998, I sent a sheet of dental X-ray film up on a flight in an effort to detect cosmic rays. Of course, there were no signs of cosmic rays on the developed film.

Plastic Sheets

The collision between cosmic rays and some types of plastics damages the molecules of the plastic. An etchant will preferentially etch away the damaged plastic, creating a cone-shaped pit where the cosmic ray impacted the plastic. The type of etchant used depends on the type of plastic, but most etchants are either strong acids or bases.

The depth of the pit etched in the plastic reveals the energy of the cosmic ray responsible for the collision. The plastic visors of some of the Apollo astronauts were treated with an etchant in order to detect some of the cosmic rays that the astronauts were exposed to on their way to the Moon. An excellent source of information on this process can be found in the book *Nuclear Tracks in Solids*, by Fleischer.

A Cosmic Trip Through Earth's Atmosphere

Slamming Into Air

To a cosmic ray, our atmosphere

acts like a 13-foot-thick slab of concrete. This is a good thing for us, since we don't handle extreme exposures to radiation very well. A cosmic ray diving into the Earth's atmosphere is called a primary cosmic ray. The flux of primary cosmic rays at the top of the atmosphere is about one cosmic ray per square centimeter per second — or about the same flux of raindrops during a rain shower.

Secondary Cosmic Ray Production

When cosmic rays slam into Earth's atmosphere, they are primarily colliding with nitrogen and oxygen molecules. Upon impact, the primary cosmic ray shatters the molecule, creating a shower of lower energy particles from the subatomic zoo — subatomic particles, like neutral and charged pions, neutrons, and more protons. Neutral pions decay into gamma rays, which later create electron-positron pairs. Charged pions decay into muons, a heavier relative of the electron. This shower of particles created by the

Solution to the Voltage Divider Question

As you will recall, in the July column, I asked the question, "How can we prove that using a fixed resistor of a value equal to the geometric mean of the range of a variable resistor yields the greatest range in values in the voltage divider circuit?" Well, the readers of this column replied with the answer.

I will send Treasure Valley Near Space Program patches to the first two responses because, together, they showed me the way to mathematically prove my observation. By the time this column goes out, Erick McAfee of Texas and Colorado College Physics Professor Val Veir should have their patches. The patches were carried to an altitude of 104,571 feet onboard my near spacecraft launches at the Great Plains Super Launch on July 3, 2004.

From Erick and Val's suggestions, plus A. A. Klaf's book *Calculus Refresher* (great book, by the way) and some fooling around on my part, I have put together the following proof.

The Plan of Attack

The voltage range generated by a voltage divider is equal to the maximum voltage generated by the divider, minus the minimum voltage generated by the voltage divider. If the output voltage of the voltage divider is graphed with respect to the possible values of the fixed resistor, we get a curve that is low on its two extreme ends and has a peak value somewhere near the middle. That peak value of the voltage range will occur at a point over the fixed resistor value that is equal to the geometric mean of the maximum and minimum resistance values of the variable resistor.

By using calculus, we can make this into a max-min problem and find the point at which the slope of the output voltage curve goes to zero (this is at its peak value). At this point, we will find that the value of the fixed resistor is equal to the square root of the product of the minimum and maximum resistances of the variable resistor or, in other words, the geometric mean of the maximum and minimum values of the variable resistor.

The Proof

We begin with:

$V = V_{max} - V_{min}$

Note that:

$V_{max} = V_A \cdot [R_{fixed} / (R_{fixed} + R_{min})]$

and

$V_{min} = V_A \cdot [R_{fixed} / (R_{fixed} + R_{max})]$

I'm going to drop V_A (the voltage applied to the voltage divider circuit) from the math, since it's just a constant and doesn't affect the best value of the fixed resistor.

Making my substitution, I get the following:

$V = [R_{fixed} / (R_{fixed} + R_{min})] - [R_{fixed} / (R_{fixed} + R_{max})]$

Now, take the derivative with respect to the fixed resistor value and set everything equal to zero:

$V / d R_{fixed} =$

$d[R_{fixed} / (R_{fixed} + R_{min})] / d R_{fixed} - d[R_{fixed} / (R_{fixed} + R_{max})] / d R_{fixed} = 0$

According to A.A. Klaf, the derivative of the equation $S = R / (R + A)$ with respect to R is equal to $A / (R + A)^2$

Making this substitution, I get the following:

$R_{min} / (R_{fixed} + R_{min})^2 - R_{max} / (R_{fixed} + R_{max})^2 = 0$

Flip the ratios (by moving them to the opposite side of the equality), multiply out the squared numerator, and we get:

$(R_{fixed}^2 + 2R_{fixed}R_{max} + R_{max}^2) / R_{max} - (R_{fixed}^2 + 2R_{fixed} R_{min} + R_{min}^2) / R_{min} = 0$

Divide the terms by either R_{min} or R_{max} (the value in the denominator) and we'll have:

$R_{fixed}^2 / R_{max} + 2R_{fixed} + R_{max} - (R_{fixed}^2 / R_{min} + 2R_{fixed} + R_{min}) = 0$

Note that we can move the minus sign into the second half of the equation and subtract the 2Rfixed to end up with:

$R_{fixed}^2 / R_{max} + R_{max} - R_{fixed}^2 / R_{min} - R_{min} = 0$

Combining like terms and moving them to opposites of the equation gives us:

$R_{fixed}^2 / R_{max} - R_{fixed}^2 / R_{min} = R_{max} - R_{min}$

Factor out the R_{fixed}^2 and move the remainder to the other side of the equation and we get:

$R_{fixed}^2 = (R_{max} - R_{min}) / (1/ R_{max} - 1 / R_{min})$

Now, at this point, I ran into a brick wall, but, knowing what I had and what I wanted, I discovered the following equation by playing around with some algebra:

$R_{min} R_{max} (1 / R_{min} - 1 / R_{max}) = R_{max} - R_{min}$

I substitute in the left side of the equation for the $R_{max} - R_{min}$ in the previous equation to get the following:

$R_{fixed}^2 = R_{min} R_{max} (1 / R_{min} - 1 / R_{max}) / (1 / R_{max} - 1 / R_{min})$

Divide out the like terms and we get:

$R_{fixed}^2 = R_{min} R_{max}$

So, the condition of having the maximum voltage range occurs when:

$R_{fixed}^2 = R_{min} R_{max}$

or when the value of the fixed resistance is equal to the geometric mean of the maximum and minimum resistances of the variable resistor.

collision of a cosmic ray is called a secondary shower.

Particles in the secondary shower continue traveling toward the surface, sometimes colliding with other molecules lower in the atmosphere and creating more secondary showers. Eventually, secondary showers are attenuated by the Earth's atmosphere, protecting us from harm. There can be millions of subatomic particles in a secondary shower and they can cover several acres of land once they reach the ground.

The secondary cosmic rays detected on the Earth's surface are mostly muons. On average, there are close to 100 of these muons impacting every square yard of land per second. Some of the surviving primary cosmic rays are so energetic that they can be detected in deep mines.

Effects

Aircraft pilots and their passengers receive less protection from cosmic rays by the Earth's atmosphere than we do at sea level. Even residents of Denver, CO (sorry EOSS) receive more radiation cosmic rays than do residents of San Diego, CA. Not only is the flux of cosmic rays greater at higher altitudes, but the flux of cosmic rays also increases the closer the aircraft flies to the geomagnetic poles. The flux is greater near the magnetic poles of the Earth because the Earth's magnetic field dips earthward and funnels cosmic rays to the surface.

The muons found in cosmic ray showers have very short half lives. Their half lives are so short that, if it wasn't for the time dilation caused by their relativistic speeds, muons would never live long enough to make the trip down to the Earth's surface, where we can detect them.

Cosmic rays may modify the Earth's ionosphere, influence cloud production, affect the ozone layer, and possibly have an impact on our weather. Cosmic rays convert some of the nitrogen-14 atoms in our atmosphere into the carbon-14 isotope, giving archeologists a great method of dating (radiocarbon dating) organic artifacts that are less than 50,000 years old.

There are several good sources of information on cosmic rays, like the book *A Thin Cosmic Rain* by Friedlander and several Internet sources. (I didn't have a problem with finding nonsense when doing my Internet search — unlike what occurs with some topics.)

Detecting Cosmic Rays with the Aware Electronics RM-60

My tool of choice for measuring cosmic rays in near space is the RM-60 Geiger counter. This Geiger counter is manufactured by Aware Electronics (**www.aw-el.com**) as a PC- or laptop-based radiation detection system. The RM-60 measures 1-1/4" by 2-3/8" by 4-3/8" and weighs a mere 4 oz. It's designed to take its power (5 to 9 volts at about 2 mA) from the serial port of a PC. Software loaded on the PC records and graphs the detections from the RM-60.

The manual that comes with each unit is very thorough and even contains background information and suggested experiments.

The output from the RM-60 is a constant +5 volt signal until an event is recorded. At that point, the voltage drops to 0 volts for the length of the GM tube's dead time. The BASIC Stamp is quite capable of detecting radiation from the RM-60.

You only need to modify a phone cable to interface the RM-60 to the BASIC Stamp. Imagine adding a radiation detector to your BOE-BOT. To interface the RM-60, you will need a telephone cable (the kind with RJ-11 jacks on both ends) and a method to connect one end of the phone cable to your BASIC Stamp.

In a future column, I will discuss the flight computer I use and how I interface sensors to it.

For now, however, you can wire the RM-60 to a Board of Education (BOE) and launch that on your near spacecraft. Let's modify the phone cable. You'll need about 10 minutes to do this.

1. Cut one end off the telephone cable (the other end is left in place so it can plug into the RM-60).

2. Strip about 1" of outer insulation

Figure 2. The RM-60 Geiger counter.

from the cut end of the phone cable. (Be careful not to damage the insulation around the wires inside

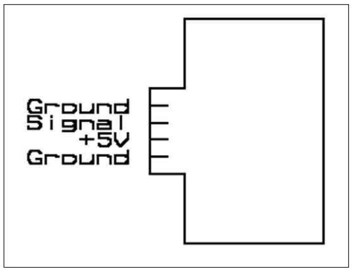


Figure 3. RM-60 pinouts.

the cable.)

3. Carefully strip about 1/2" of insulation from each of the four wires inside the cable. (This is a very small gauge wire.)

4. Bring the two outer wires together and solder them together. (They are connected to ground.)

5. The second wire is the 5 volt signal from the RM-60. This wire is connected to a BASIC Stamp I/O pin.

6. The third wire is the 5 volt supply to the RM-60. This wire is connected to the 5 volt output from the BASIC Stamp. Even in high radiation environments, its current draw does not exceed 20 mA — well within the capability of the Stamp's built-in voltage regulator.

The diagram in Figure 3 is looking into the open socket of the RM-60. I have accidentally crossed my wires without ill effect to the RM-60.

The OnSet Prize

The OnSet Computer Corporation (**http://onsetcomp.com**) has generously agreed to sponsor a prize for the highest altitude amateur near space flight during the 2004 calendar year. This is the largest sponsorship to amateur near space exploration to date. By achieving the highest altitude flight this year, you will win the following OnSet products:

• A four channel, eight-bit HOBO Data Logger that measures relative humidity, temperature, light intensity, and one external voltage of your choice.

• Boxcar Pro 4 software for programming the HOBO, downloading data collected by the HOBO, graphing and analyzing data, and exporting the results to other file formats.

• An external temperature sensor (on a six foot cable) for the HOBO Data Logger.

This award is a miniature weather station for your near spacecraft and would be a part of an awesome science fair project. With the OnSet Prize, you can measure the internal temperature of your near spacecraft, the outside air temperature, the relative humidity of the air, and the Sun's intensity during flight. With these measurements, you can determine the height of the stratosphere and how it varies over the course of the year. You can also determine the rotation rate of your near spacecraft. It's very difficult to get this kind of data from a near space mission at the extremely low weight of the HOBO Data Logger and its sensors.

To be eligible for the OnSet Prize, you must accomplish the following:

1. Announce your flight at least a week prior to launch (the general launch location, callsign of the near spacecraft, and its frequency).

2. Use a GPS receiver and APRS to transmit position data during the mission.

3. Transmit APRS data such that other amateur radio operators can record the data.

4. Obey FAR 101 requirements.

5. Recover the near spacecraft.

6. Announce the results of the flight (include several packets or posits around the peak altitude).

I monitor several amateur near space group Email lists. I recommend making your announcement either on the EOSS Balloon Launch Announcement list, the KNSP Email list, or the GPSL Email list. All these groups are available to the public from Yahoo Groups.

If at all possible, please transmit your flight related packets or posits to a gateway and to the Findu website. In this way, everyone can monitor the flight.

Be sure to get my attention when you announce your peak altitude. I'll Email a reply to all announcements.

In December or once no other near space groups announce that they will launch a mission before the end of the year, I will announce the winner. Since I'm a high school teacher and take road trips during Christmas break, I will try to present the award personally. If that can't be arranged, I will send the award through the mail.

I'd like to thank OnSet Computer Corporation for sponsoring this prize. You'll find their products in the NASA Space Grant Consortium's BalloonSat Program. Be sure to check out the OnSet website and get a look at the great products they offer. You'll find a lot of justifications for launching near space missions with OnSet Computing Corporation.

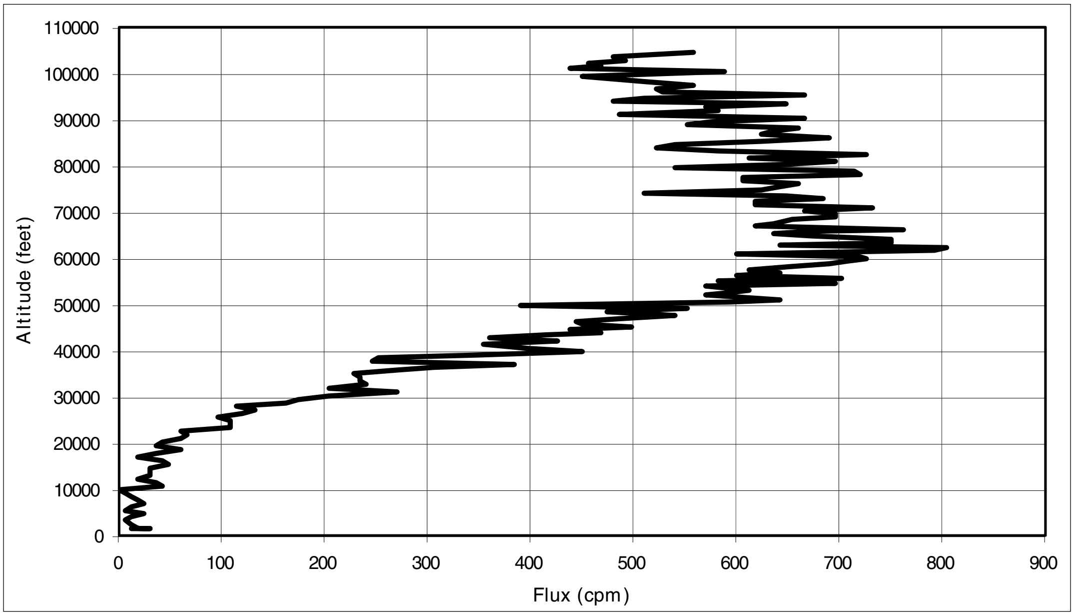


Figure 4. Cosmic ray flux.

However, I do not recommend you do this, as I may have been lucky.

I like to solder the wires of the telephone cable to a straight male header with 0.1" between centers. This type of header is available from Jameco as part number 109575. I tin each wire and then slide thin heat shrink tubing over it.

Next, I tin the short pins in the header and press a tinned wire in contact with a header pin and heat them with a soldering iron.

The solder on the wire and the header pin melts and fuses the wire to the pin. After it cools, I slide the heat shrink over the soldered connection and shrink the tubing. Afterward, I can plug the RM-60 into the BOE's breadboard or my flight computer, like I would a servo.

I use the following code to determine the counts per minute from the RM-60. My code is written for the BS2pe, so you will need to modify the count time if you use a different flavor of BASIC Stamp. On my flight computer, I store the results into a RAM Pack B. If you are sending up an RM-60 with your BOE, then you can store the results in the EEPROM of the Stamp. After recovery, you can download the results of the flight.

```
gm              CON     0
radiation       VAR     WORD

Geiger_Counter:
  COUNT gm,34843,radiation
  DEBUG DEC radiation
```

This code assumes the RM-60 is connected to P0 and counts the number of pulses from the RM-60 for 10 seconds. Since I have so many other experiments onboard my near spacecraft, my flight computer can only afford to count cosmic rays for 10 seconds at a time. After recovery, I download the results from the Geiger counter into a spreadsheet and multiply the results by six to get the cosmic ray flux in units of counts per minute.

In your experiments, you should count cosmic rays at a fixed interval. Use the APRS data from your near spacecraft to determine the altitude at each measurement. When you combine the cosmic ray count with the altitude in a spreadsheet, you generate a chart like the one in Figure 4. It shows data that was recorded and collected at the Great Plains Super Launch on July 3, 2004. My near spacecraft weighed nine pounds and made an altitude of 104,571 feet on a 1,500 gram balloon with 15 pounds of lift.

This chart is typical of what my near spacecraft measure. The flux increases with increasing altitude, as Viktor Hess would be familiar with. The cosmic ray flux increases until an altitude of 62,000 feet is reached. Higher than that, the cosmic ray flux decreases. t appears that the drop in cosmic ray flux occurs because the near spacecraft enters a region where there are primary cosmic rays that have not yet produced cosmic ray showers. There really are fewer cosmic rays to detect, but each detection on average contains more energy.

Had this flight occurred shortly after a solar flare, the cosmic ray flux most likely would have continued increasing above 62,000 feet. If the mission had taken place closer to the geomagnetic poles, the increase in cosmic ray flux would have climbed more rapidly.

So, get out there and start using the RM-60. For $150.00, it's a great little Geiger counter. I do not work for Aware Electronics and I don't receive compensation from them. I'm just a satisfied customer. Let me know how your Geiger counter experiments turn out. Remember that you can contact the amateur near space group closest to you and arrange for them to carry your experiment into near space.

Onwards and Upwards,
Your Near Space Guide **NV**

Resources

Parallax — **www.parallax.com**
Aware Electronics — **www.aw-el.com**
Jameco — **www.jameco.com**
OnSet — **http://onsetcomp.com**

Tech Forum

QUESTIONS

We have a 2001 VW Eurovan that had three keys, two of which are the remote control key fob type, and one smaller "valet" key. My wife has lost both of the remote keys, somewhere here in our house. The dealer wants over $200.00 per key to replace them. I tried to copy the remaining key at our local home center. They were able to grind a new key blank, but a tester showed that the original had an RF chip that prevents the copied key from being used.

Can a device be made or purchased that will emulate the signal the car sends to excite the RF chip and detect if a key is nearby? I could use that to search our house for the key. If it can tell me if a key is close by, that would enable me to narrow our search and find it without tearing the whole house apart.

#9041 **Jim Balderrama**
San Diego, CA

I am trying to find info on a kit that was offered back in *Radio Electronics* magazine, called the HyperClock. It was offered by an outfit named SkiTronix, around 1991. I built one back in high school, and it has just now failed. I cannot locate the schematics or magazine issue that featured it. Searching the web has not yielded anything.

#9042 **Rich White**
via Internet

Does anyone have a simple circuit for taming the turn-on thump from the charging of the output coupling capacitor of a bass guitar amp that uses a single 90-volt supply? Manual switching is not adequate because it does not protect against someone messing with the power cord wall plug.

#9043 **Dennis Green**
via Internet

We use a Barcus Berry model Model 4000N piano mic at our church. Remembering to change batteries every couple of months before we are in the middle of a service is a pain. I want to convert our mic to be phantom powered from our audio mixer. Has anyone done this and can offer some advice?

#9044 **Steven Morgan**
Cumming, GA

I do quite a lot of 35mm motion picture projection work, and wonder how close to 24 frames per second the projector is actually operating. Is there a circuit for some sort of sensor that I can hold in front of the lens and measure the FPS count?

#9045 **Edward Vanoverschelde**
Buhl, ID

I have two questions. First, what happens when an EXE file is run on a PC? I would like to know where the contents of an EXE file will be loaded, and so on. Second, I am confused with partitions on the hard disk drive. I would like to know how the partitions (i.e., C, D, etc.) are represented on the disk.

#9046 **Aditya**
via Internet

This is a READER-TO-READER Column. All questions AND answers will be provided by *Nuts & Volts* readers and are intended to promote the exchange of ideas and provide assistance for solving problems of a technical nature. All questions submitted are subject to editing and will be published on a space available basis if deemed suitable to the publisher. All answers are submitted by readers and NO GUARANTEES WHATSOEVER are made by the publisher. The implementation of any answer printed in this column may require varying degrees of technical experience and should only be attempted by qualified individuals. Always use common sense and good judgement!

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ANSWER INFO

- Include the question number that appears directly below the question you are responding to.
- Payment of $25.00 will be sent if your answer is printed. Be sure to include your mailing address if responding by email or we can not send payment.
- Your name, city, and state, will be printed in the magazine, unless you notify us otherwise. If you want your email address printed also, indicate to that effect.
- Comments regarding answers printed in this column may be printed in the Reader Feedback section if space allows.

QUESTION INFO

To be considered

All questions should relate to one or more of the following:

1) Circuit Design
2) Electronic Theory
3) Problem Solving
4) Other Similar Topics

Information/Restrictions

- No questions will be accepted that offer equipment for sale or equipment wanted to buy.
- Selected questions will be printed one time on a space available basis.
- Questions may be subject to editing.

Helpful Hints

- Be brief but include all pertinent information. If no one knows what you're asking, you won't get any response (and we probably won't print it either).
- Write legibly (or type). If we can't read it, we'll throw it away.
- Include your Name, Address, Phone Number, and Email. Only your name, city, and state will be published with the question, but we may need to contact you.

ANSWERS

[6041 - June 2004]

Does anyone know how I might construct a relatively simple field strength meter to orient a UHF antenna while I'm perched on a ladder? The circuit would be tuned to one specific frequency — say 500 MHz.

#1 I used to work on TV antennas for Sears and couldn't stomach the $300.00 price of an antenna meter,

so I bought a $50.00, AC/DC, 5 inch, B&W TV from RadioShack and brought the AGC voltage to a jack in the rear. It goes up the ladder just fine and runs on batteries if you don't want to sling a 50 foot extension cord up on the roof. My DVM shows me when I'm aimed right, and the picture helps me see if I have ghosts. It's better than any expensive field strength meter, and the frequency is continuously, manually, tunable.

C. L. Larson
Largo, FL

#2 In order to build a suitable UHF field strength meter, you'd be looking at a sizeable outlay to get the sensitivity required. An easier way is to borrow a pair of FRS radios, station one with a viewer at the TV set while you orient the antenna on the desired channel. Moving the antenna back and forth until an average mid point results in best reception. The FRS radios serve as communication between you and the TV observer. This method is suitable for any frequency range of interest.

Ralph Cameron
Ottawa, Ontario, Canada

[6044 - June 2004]

If I were to take two 500,000 volt stun guns and connect both positive outputs together and both negative outputs together, would I have 1,000,000 volts? I'm planning an experiment which uses high voltage.

#1 NO. In the first place, the output should be connected in series, plus to minus. But the outputs are not DC and not the same frequency, so they don't necessarily add. However, I would expect the voltage to be more than one alone.

Russ Kincaid
Milford, NH

#2 Such a simple question — but one for which a technically accurate answer is horrendously complicated. As for the proposed experimentation — DON'T TRY IT!!!

The insulation on those devices — while good enough for the voltage they produce — is NOT adequate to contain double that voltage, nor anything even close to double it. Not to mention the difficulty you will have in finding something with adequate insulation, to use to tie them together.

If you try this experiment, it is virtually guaranteed that you'll have some form of catastrophic failure, with destruction of the gear, and serious hazard to life and limb.

The semi-safe way to experiment with 'very high' voltages is with static electricity. Search the Internet for 'Wimhurst static machine' or 'Van de Graaf generator' for some starting points. *(Also check out Gerard Fonte's four-part Enigma Machine project, beginning in the June 2004 issue of Nuts & Volts. — Editor Dan)*

Robert Bonomi
Evanston, IL

[7041 - July 2004]

I have three radios that use an LM386 for the audio output. This chip tends to be noisy. (It produces audio hiss.) Are there any circuit modifications that can be applied to this chip to make it less noisy?

The LM386 is a very old chip that is still around because it works well. It is also well known for generating hiss. The most common solution is a 10K resistor and 0.01 mF capacitor in series between pins 5 and 8. This provides feedback that reduces the high frequency response and therefore the hiss heard at the speaker.

Dave Sarraf
Elizabethtown, PA

[7042 - July 2004]

I have been looking for years for a circuit to sense cars in my driveway. I know that the traffic lights use a single wire loop in the pavement and I assume that it is some kind of tank circuit tied to a PLL. I would appreciate any information on the subject.

#1 I worked on a loop detector design in 1967. The technology has changed, but the theory hasn't. Design an oscillator for about 100 kHz, with the loop as part of the tank circuit. Cut a slot in the pavement and lay outdoor insulated house wire in the trench and backfill with epoxy. A few turns are all that's needed. When a car enters the loop, the frequency will increase by between 1% and 3 %. The frequency will also change with temperature, moisture, etc. The detection threshold has to be slowly balanced in 10 minutes or so. We used phase locked loops, but counting the frequency with a microcomputer is much easier.

James Vaughan
Bainbridge Island, WA

#2 Old traffic lights used the inductive wire you mention. Modern traffic lights use video cameras to sense when vehicles are present. The cameras are usually mounted on the horizontal support that the traffic light is on. Most people think the cameras are monitored by people at a central traffic office — they are not. They are just local cameras connected to the traffic signal control box. The reason they went to video was that it was too expensive to cut the road to lay the wire. Plus, there were maintenance problems with the wire method.

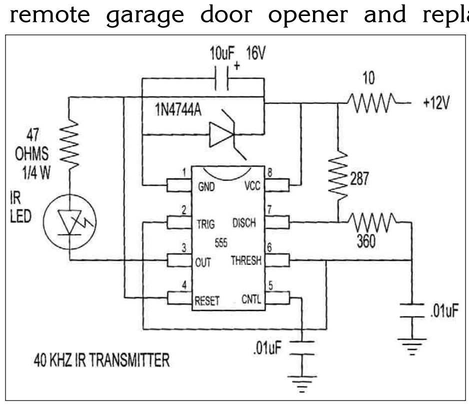
If you wish to use the same method to "watch" your driveway, there is a plug and play solution. Resources Un-Ltd. (**www.resunltd4u.com**) has a VM10, which is a video motion sensor. Attach a video camera to the unit and whenever a change in the scene is detected, the unit will buzz. It sells for $179.00 and also has contacts for a VCR.

Jon B. Bushey
via Internet

[6042 - June 2004]

I would like to have my garage open automatically when I pull in the driveway. Maybe an IR transmitter on my garage and a receiver in my car? The IR on the garage could transmit a constant signal so that when the receiver (in my car) picked it up, the door would automatically open. Any suggestions?

Wow! Too lazy to push a button! I understand your need to have the receiver in the car, so only your car will open the door. But you need a transmitter in the car and receiver in the garage to operate the motor that opens the door. I suggest that you remove the push button from the remote garage door opener and replace it with an IR receiver module. These receivers operate at a frequency of 40 kHz, so you will need an IR transmitter running at that frequency. The circuit shown here should produce enough power, but you may need some optics to direct it to the driveway.



Russel Kincaid
via Internet

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